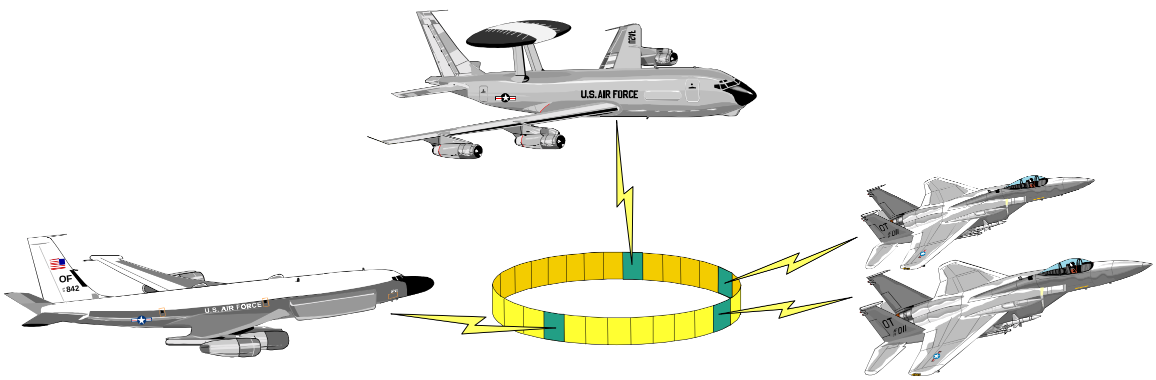
Link 16 Operations for the Air Force Wing and Unit Manager

October 1999



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Abstract

The Air Force has defined points of contact (POCs) at wing and unit level to act as Link 16 experts and interfaces between wing/unit and other elements of the Link 16 operational infrastructure. The goal of the document is to explain the duties of the wing/unit manager sufficiently to permit him to execute those duties. The document is focused on the F-15C, E-3 and Rivet Joint platforms. It is essentially a written version of a one-day lecture developed for the wing/unit managers for those platforms. However, while it focuses on those platforms, it should be useful to other platform operators as well.

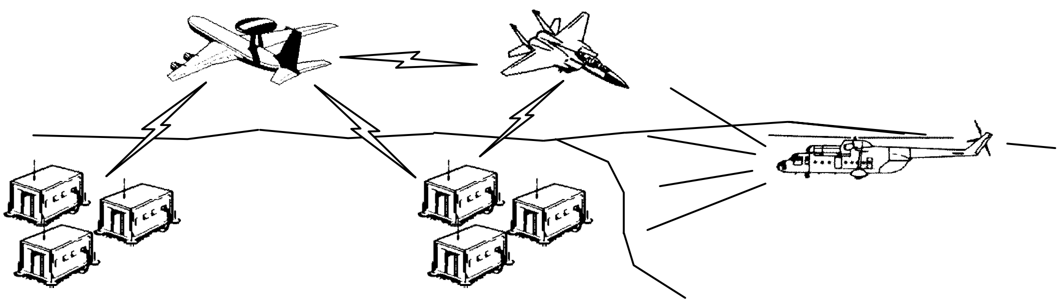
The approach taken is to begin with a description of the basic Link 16 architecture and three critical modes of operation. This provides a broad technical background supporting the rest of the material. It is followed by an initial description of the network management process. In the initial network management section, the network management process is described, the duties of the wing/unit manager defined and the preparation of the OPTASK LINK discussed, but only to the extent that the material in the previous sections provides the reader with the necessary technical understanding. Following the network management section, a series of topics are presented. For each topic, the theory of operation is described, then additional duties of the wing/unit manager and the additional elements of the OPTASK LINK for which a technical understanding has been provided are presented. We also build a network troubleshooting guide. At the end of the topics, the wing manager duties are summarized, the complete troubleshooting guide is presented, and the complete OPTASK LINK message is discussed in a second network management section.

KEYWORDS: Wing Manager, Unit Manager, Link 16, JTIDS, MIDS

Table of Contents

1.0 Introduction

This document is intended to support Air Force Link 16 wing and unit managers. It is essentially a written version of a one-day lecture developed for the same purpose. The concept for the document is to build sections and subsections around picture vugraphs. Each subsection will have an associated figure which is numbered and titled consistent with the section to which it is subordinate[1]. We begin with an introduction which provides a short overview of Link 16, defines the functions of wing and unit manager, and describes the document's content. The document then proceeds to address the functions in some detail. We expect the document to evolve with subsequent versions, with topics being added and modifications made based on user comments. All comments are welcomed by the author[2].



1.1-1 Introduction - What Link 16 is

Link 16 is a high capacity, jam resistant tactical data link. Security is built into the system with the base band data being encrypted (message security) and the basic waveform being a function of cryptokey so that the waveform looks very much like noise to a receiver which does not hold the associated key (transmission security). High data rate and jam resistance requires a good deal of radio frequency (RF) bandwidth and that bandwidth was found between 960 and 1215 MHz. Due to its high frequency, Link 16 is limited to line-of-sight exchanges. However, the communication terminals required to operate the data link all contain the capability to relay, and the Link 16 data exchange can thereby be extended beyond line of sight. In the figure the E-3 is shown relaying between the two Control and Reporting Elements (CREs), one located in the forward area near the forward edge of the battle area (FEBA) and the other located to the rear. In addition, the relay of information from platforms located in the rear by forward units can help to defeat a jammer threat. An example is the forward CRE relaying from the E-3 to the F-15. Even with the relay capability, Link 16 networks normally extend no more than 700 to 1000 nautical miles (nm). The tactical data link is intended for communications within theater, not long haul.

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[1] If a subsection takes only one page the figure is at the top. If it takes more than one page the figure is at the top of each page and the title is repeated with numbers associating the sub-subsections, e.g., 1.2-1, 1.2-2, etc. As much as possible each section and subsection will be stand alone, so it can be used for independent reference.

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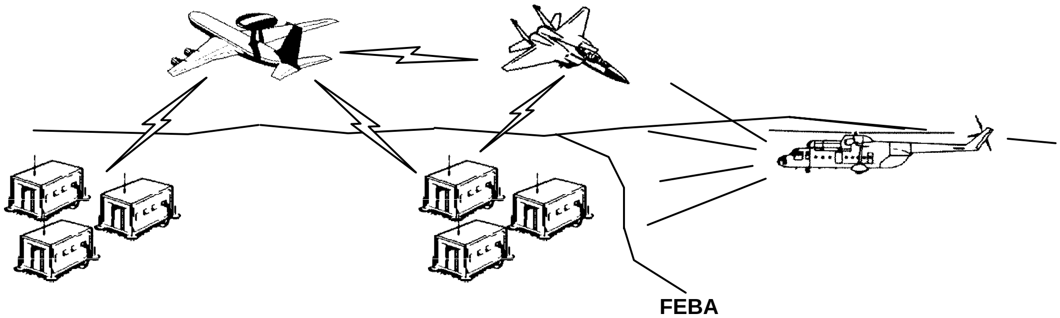
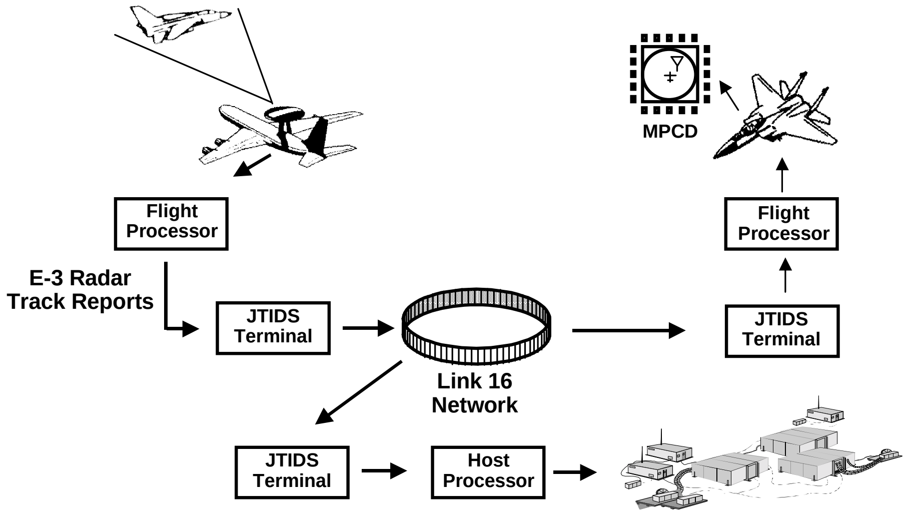


1.1-2 Introduction - What Link 16 is

The Link 16 waveform and the data sets that are exchanged are standardized and configuration managed, within the US and among our allies, to support interoperability among implementing platforms. The data link architecture requires all platforms to be time synchronized and the data link provides a means to accomplish this automatically. This time synchronization supports a relative navigation capability which can locate each Link 16 participant quite accurately relative to the other Link 16 participants. This navigation feature has been key to the use of Link 16 by the F-15Cs.



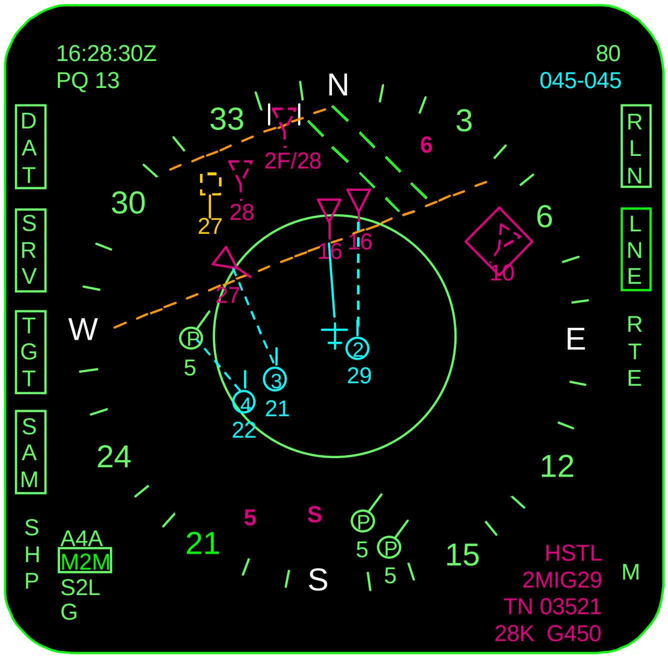
1.2 Introduction – Networks and Information Exchange

The Link 16 architecture is time division multiple access (TDMA). Time is divided into time slots, 128 slots/second, and participants are assigned time slots in which to transmit their data. When not transmitting data the participant can receive data being transmitted by other participants. It is a broadcast system, with data transmitted by one participant typically available to all participants (at least all participants who care to receive it). In order to know when a time slot occurs, all participants must be time synchronized. A group of participants all time synchronized is termed a Link 16 network. In order to know how to behave in a Link 16 network, each terminal must be provided a set of network and platform unique initialization data which assigns it time slots and how to use them (among other things).

Employment of the data link system permits combat personnel on one platform to use sensor information from other platforms, and the actions of the personnel on a platform to be reflected on the displays of other platforms in near real time. This information exchange assists the individual platforms to operate together as a single tightly integrated force. The figure illustrates the receipt of sensor information from the E-3 by an F-15 and an Air Operations Center (AOC), the information being radar track reports. Such information received by a fighter via data link is termed "off board" information.

Link 16 can be thought of as having two distinct sets of "customers". The first set is the C^2 community as represented in the figure by both the E-3 and AOC. Information regarding the location, platform status and engagement status of friendlies will flow back to the controlling units, missile units and operations center. Air situational awareness will flow back from the C^2 and surveillance platforms to the AOC. The sharing of sensor and status information permits the development of a common surveillance and engagement status picture bringing near real time situational awareness to unprecedented levels. For the C^2 community, this permits them to more effectively manage the air operation.

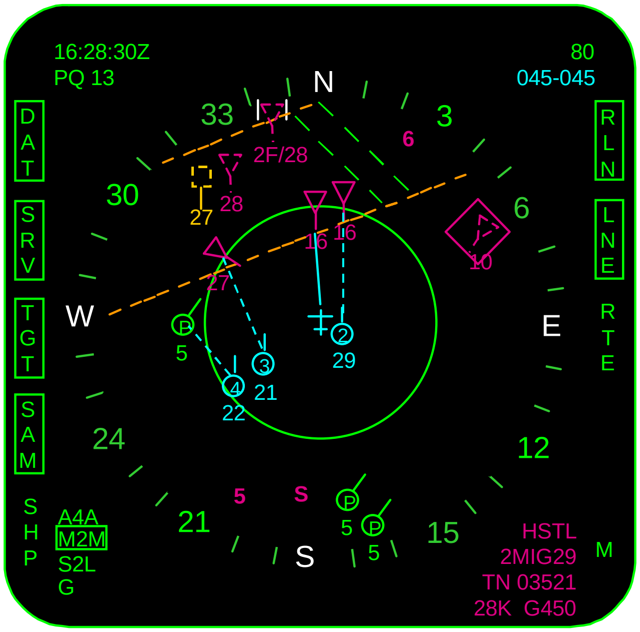
However, whereas Link 16 represents an improvement for the C^2 community, to the fighter community, the second set of users, the data link offers an entirely new capability which is revolutionary is nature. For them, Link 16 provides 360° of near real time air situational awareness at a glance during the day, at night and in all weather.



1.3-1 Introduction – Motivation

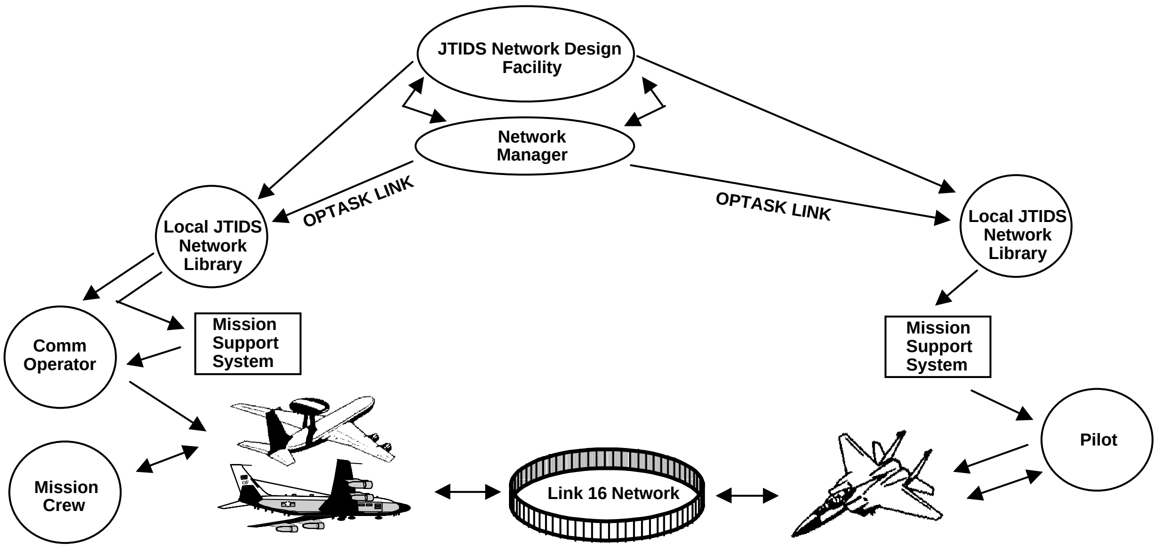
The figure provides an example of the F-15C multipurpose color display (MPCD). The display is located just below the radar Vertical Situation Display (VSD). Ownship is at the center of the display with the direction of flight up. Wingmen are shown as blue circles with their flight position inside. At a glance the pilot can see where his/her[3] flight members are. Other friendlies are shown as green circles. When the radar is in a tracking mode, radar targets are automatically transmitted on Link 16. Received targets are correlated prior to display, as red triangles for hostiles. When a fighter designates a target for a shot this cue is sent with the target and seen by wingmen as blue "lock lines", dashed for wingmen and solid for ownship. This vastly improves target sorting and reduces fratricide (i.e., seeing a green circle at the end of a lock line is a strong cue not to shoot!). Air tracks from C^2 and surveillance platforms are correlated with fighter targets and uncorrelated air tracks are displayed with dashed symbols. This provides near real time 360° situational awareness, again at a glance. In addition, track symbols can be "interrogated" by the pilot (see two white parallel lines about the hostile symbol at the top of the display) resulting in additional information in the lower right of the display. Ground threats such as active SAMs found by Rivet Joint and other sources are displayed as a red S or a numeric, if the type SAM is known (i.e., a red 6 for a SA-6). All of this provides the pilot with a god's eye view of the air situation and the ground threat in all visibility conditions, **at a glance**. It improves mutual support, assists target sorting, reduces fratricide, and alerts the pilot to air and ground threats. This can lead to dramatic improvements in the pilot's ability to kill while helping to keep him alive to kill again.

[3] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.



1.3-2 Introduction – Motivation

Link 16 has been built with a good deal of flexibility, which permits the command staff to decide how to utilize the data link capacity for a given operation by designing a Link 16 network expressly tailored to the operation. However, this flexibility makes the operation of Link 16 networks somewhat more complex than for a normal radio system, requiring a unique Link 16 network management infrastructure. So achieving the benefits of the data link will take some work. This document is intended to assist those individuals required to do that work. We believe that the pilots and C^2 operators will find its worth it.

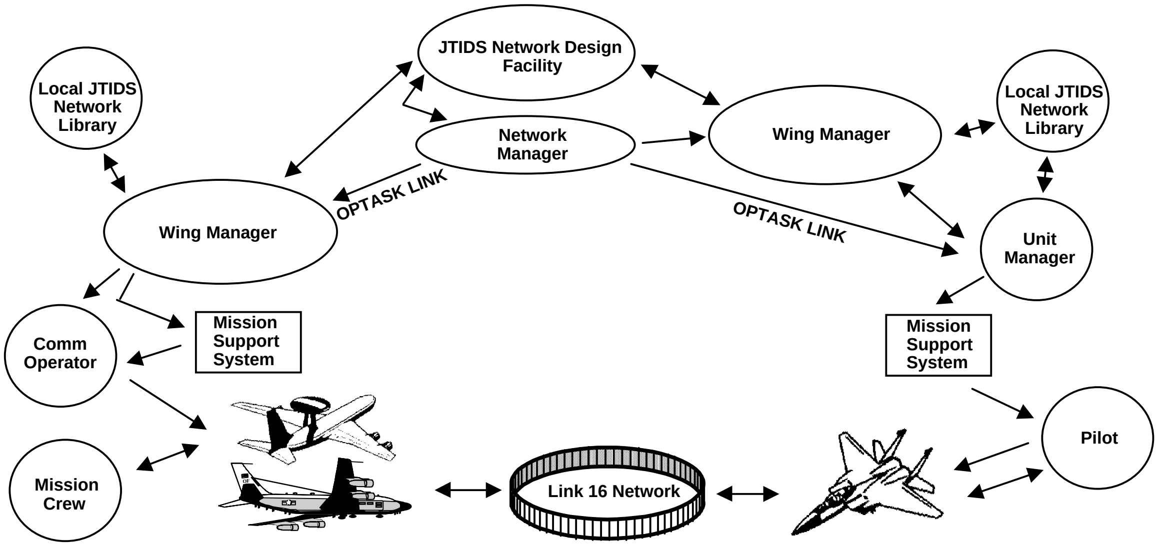


1.4 Introduction – Network Management Infrastructure

The Link 16-unique infrastructure is depicted in the figure. The operation of a Link 16 network begins and ends with the network manager. It is the network manager who formalizes the requirements for each network with such things as the types and numbers of participants, disposition of forces and information exchange requirements. This information is coordinated with the network customers and then sent to the network designer in a network request.

The network designers for the Air Force are located in the Air Force JTIDS Network Design Facility (AF JNDF) at HQ ACC. They will design the network using a computerized network design aid. The resulting network documentation will include a network description and a set of Link 16 terminal initialization data for each participant. The description and initialization data sets must be distributed to all potential network participants and held in a local library awaiting their use in an operation. Networks, once designed, are expected to be used over and over, some often, others infrequently, until they are retired from the library. Until retired from the library, the operators/pilots must have the initialization data sets for their platforms for each network on file for use.

Once the network has been defined, designed and distributed to the potential participants, the network manager can operate the network. He will assign an initialization data set to each participant and select certain participants for special roles. This information, along with other related information, is placed in the operational data link tasking message (OPTASK LINK) which is sent to all of the participants. At wing/unit level, the appropriate operator draws the initialization data set from his network library, adds the additional data specified in the OPTASK LINK and his own locally derived data, and loads the Link 16 terminal. The appropriate operator draws the proper key from the crypto custodian, fills the key load device, and keys the Link 16 terminal, also as specified in the OPTASK LINK message. The operator then directs the terminal via his platform interfaces to enter the network. Once operating in the network, the operators can begin to tactically employ the exchanged information. The network manager then monitors the network operation.



1.5 Introduction – Wing and Unit Managers

The Air Force has defined points of contact (POCs) at wing and unit level to act as Link 16 experts and interfaces between wing/unit and other elements of the Link 16 operational infrastructure. At some bases such as Tinker AFB and the 522 ACW, there is only a wing manager. At others such as Mt Home AFB, units such as the 390 FS and 726 ACS will have unit managers and there will be an overall coordinating wing manager as well. At bases which only have a single unit equipped with Link 16, there may only be a unit manager[4]. He will act as wing manager.

The wing/unit manager will act as the interface between the wing/unit and the AF JNDF. For daily training, the wing/unit manager may act as the network manager for locally operated networks. He will determine the requirements for those networks and request them of the AF JNDF. He will obtain the network descriptions and initialization data sets from the AF JNDF for all networks in which his platforms are potential participants, including joint and allied networks, and maintain them in a local JTIDS network library.

If his platforms are deploying to work in a Link 16 network being managed by another unit, the wing/unit manager will act as the interface between his individual platforms and the network manager. For locally operated training networks the wing/unit manager will act as the network manager, providing the information required to operate in the network directly to his platforms and to other participants via an OPTASK LINK message[5].

The wing/unit manager will be responsible for supporting functions regarding cryptokey, its acquisition, maintenance and terminal fill, and frequency management. Link 16 operates in the same part of the radio frequency (RF) spectrum as do radionavigation aids and the Air Traffic Control Radar Beacon System (ATCRBS), and this dictates adherence to a strict set of spectrum related system constraints and related wing manager duties.

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[4] This was the case at Mt Home AFB when only the 390 FS was equipped with Link 16. With the equipping of the 726 ACS and a B-1 bomber, the 366 WG has designated an overall wing manager.

[5] Informal procedures can be used, but this document will encourage the use of the OPTASK LINK message.

1.6-1 Introduction – Content of the Document

The goal of the document is to explain the duties of the wing/unit manager sufficiently to permit him to execute those duties. It is best if the reader has received the associated Link 16 Wing/Unit Manager's System Operations lecture, and that lecture is best received after the wing manager has attended the JTIDS 101 course taught by the Joint Multi TADIL School (JMTS) at FORSCOM. However, like the Link 16 Wing/Unit Manager's System Operations lecture, the document should be of use as a stand alone reference.

Rather than just presenting the duties of a wing manager, the document will provide a theory of operation to help the wing manager understand why he is being asked to do something. This will help him execute the duty as well as cope with problems as they come up. In addition, one of his duties is to act as the first line of Link 16 technical expertise for the wing/unit and he requires a sound theory of operation for that. In explaining Link 16, we have tried to keep the technical content appropriate for an operator, rather than an engineer. Based upon feedback from the lecture from which it is derived, some will feel that it is too technical while others will want more information. We hope it is a good compromise between the two.

As part of his duties, the wing manager will be required to both read and write an OPTASK LINK message. When his platforms are deploying to operate in a Link 16 network, the network manager of that network will (or should) provide the details regarding the network required by its participants via the OPTASK LINK message, and that message will be sent to the wing/unit manager. The wing manager will further distribute the information to his platforms and so must be able to read the message. When the wing/unit is hosting a training exercise, the wing manager will act as network manager and will (or should) prepare an OPTASK LINK message and distribute it to the wing managers[6] of the participants. So the document will discuss the preparation of the OPTASK LINK message.

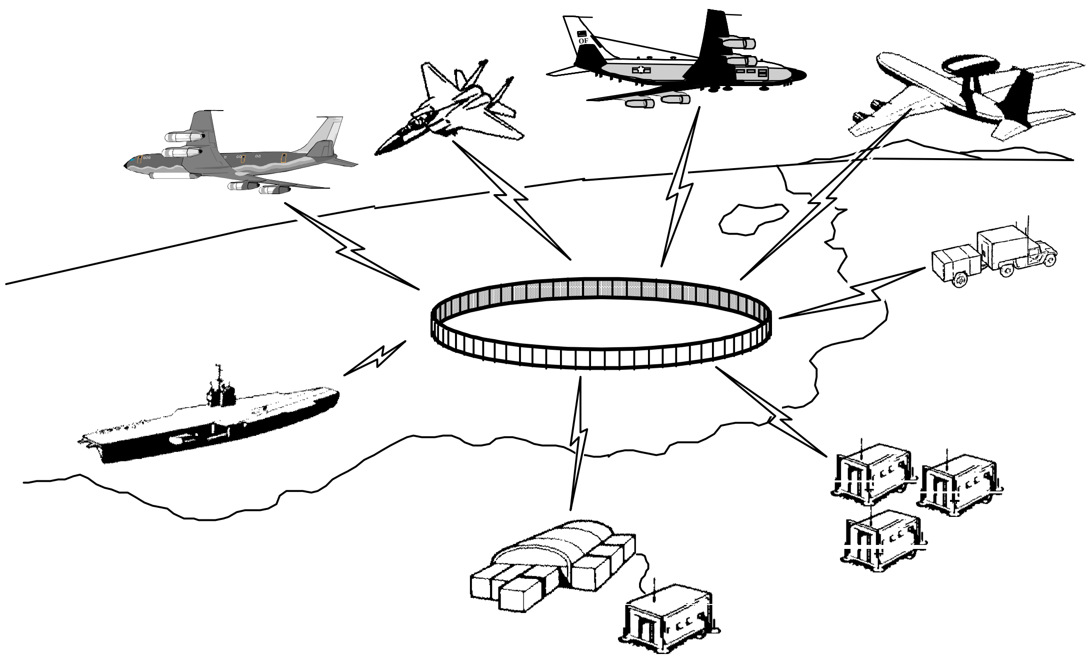
The approach taken is to begin with a description of the basic Link 16 architecture (Section 2) and three critical modes of operation (Section 3). This provides the basic technical background which past courses have shown is required for the operator to best understand the duties which follow. If the reader does not agree, he can skip right to the initial description of the network management process (Section 4). In this network management section, the network management process is described, the duties of the wing/unit manager defined and the preparation of the OPTASK LINK discussed, but only to the extent that the material in the previous three sections provides the reader with the necessary technical understanding. Duties are underlined in the text for emphasis and summarized at the end of the section. Following the network management section, a series of topics are presented, i.e., track numbering (Section 5), synchronization (Section 6), cryptokey utilization (Section 7), frequency management (Section 8) and navigation (Section 9). The navigation section is mostly for the F-15C wing/unit managers. The sections of the document and the subsections are made as stand alone as possible to facilitate their use for reference[7]. For each topic, the theory of operation is described, then additional duties of the

[6] Or appropriate Link 16 POC for the other services.

[7] For example, if an operator wishes to better understand the external time reference approach to synchronization, he can go directly to the Synchronization - External Time Reference (ETR) subsection.

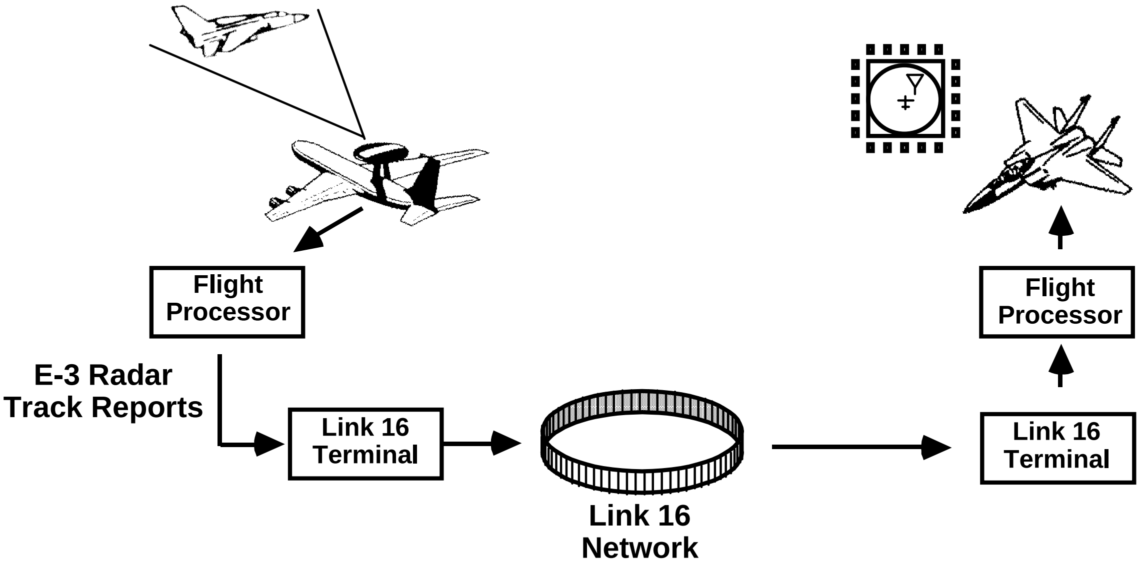
wing/unit manager and the additional elements of the OPTASK LINK for which a technical understanding has been provided are presented. As with the network management section, duties are underlined in the text and summarized at the end of each section. In addition, starting with synchronization we build a troubleshooting guide. At the end of the topics, the wing manager duties are summarized in a wing/unit manager's checklist, the complete troubleshooting guide is presented, and the complete OPTASK LINK message is presented in a second network management section (Section 10).

2.0 Architecture



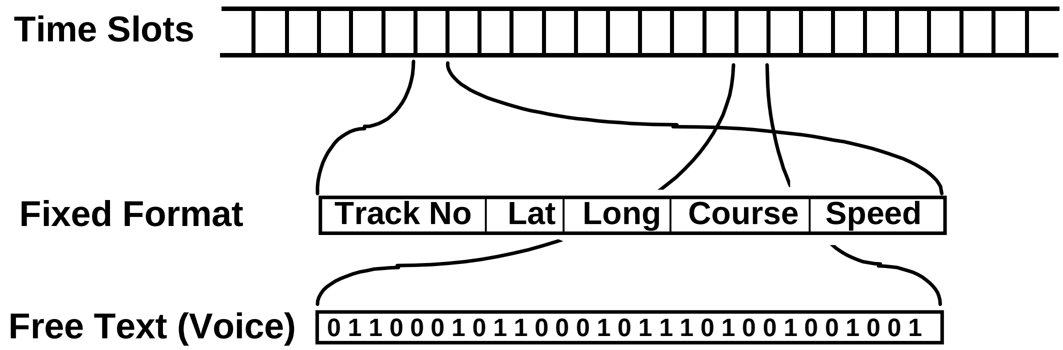
2.1 Architecture – Time Division Multiple Access (TDMA)

The Link 16 architecture is time division multiple access (TDMA). Time is divided into time slots, 128 slots/second, and participants are assigned time slots in which to transmit their data. When not transmitting data the participant can receive data being transmitted by other participants. It is a broadcast system, with data transmitted by one participant typically available to all participants (at least all participants who care to receive it). In order to know when a time slot occurs, all participants must be time synchronized. A group of participants all time synchronized is termed a Link 16 network.



2.2 Architecture – How Link 16 Works

Although the Link 16 terminals are not cheap, they can be viewed as nothing more than digital radios with which processors of the host platforms can exchange digital data. The task of generating the data for transmission and effectively displaying received data to an end-user operator (e.g., F-15C pilot) belongs to the host processors. Therefore, integration of a Link 16 terminal into a platform not only requires the physical integration of the terminal, but the development of host processor software and the installation of any new host platform equipments (displays, operator entry devices, data buses, or auxiliary processors) required to make use of the data exchanged via the terminal. As an example, the E-3 radar receives hits from a target by its radar. The sequential series of hits are correlated by the flight processor and an E-3 track established. Periodically the track data base is accessed by the flight processor and a Link 16 track report built and sent to the Link 16 terminal for transmission on the Link 16 network. It is received by the Link 16 terminal in the F-15C and is sent to the F-15C flight processor which sets up a received track data base. The flight processor then screens the data base by range, track type, etc. and generates a “user friendly” display for the F-15C pilot in a format consistent with the other displayed information. The end-to-end interoperability of this exchange is more a function of the on-board systems and flight processor mechanization than the terminal-to-terminal exchange. Fortunately Boeing-St. Louis has done an excellent job of integration and this has led to the positive response of the F-15C pilots.



2.3 Architecture – Approach to Data Exchange

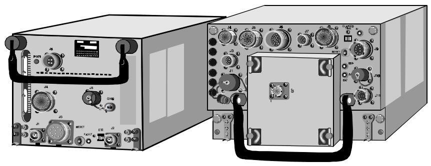
For the most part, Link 16 data is exchanged using fixed format messages. The users of the data link hypothesize the uses to which it will be put and the information which will have to be exchanged to support those uses. Air track reports transmitted by the E-3 are an example of such information. The information is defined in terms of messages and rules for reporting them. Examples of messages are the air track message and the track management message. Surveillance platforms will transmit air track messages for tracks they wish to report on the data link with a 12 second update interval and conclude their transmission with a track management message indicating a dropped track when a track is lost. The length of each message in bits of data[1] is established and the content of the message is mapped onto the bits. For example, the air track message will include a track number (TN) to identify each track, latitude, longitude, course, speed, identity, etc. The number of bits associated with each field is established along with each field's location in the message. For quantities such as latitude, the number of bits and their value will establish the resolution of the field. For items such as identity, the number of bits will establish the number of possible different identities and each possible value will be defined (e.g., 0-friend, 1-hostile, 2-unknown, etc.). The messages and their transmission rules are codified in a data link standard (MIL STD 6016) and is configuration managed by the users.

The data link standard directly supports interoperability among the Link 16 network participants. For example, by reference to the standard, Boeing-Seattle engineers can design software for the E-3 which will build air tracks which can be properly interpreted by F-15 software designed by Boeing-St Louis engineers for unambiguous display to the pilot.

There is another format which can be used and that is called free text. To date, its operational use has been limited to voice. The voice signal from a microphone is sent to the terminal where it is digitized and the bits sent in a JTIDS time slot. On the receiving end the bits are used to reassemble the voice signal which is sent to the host platform to be heard on a speaker/headset. The free text format has also been used experimentally to exchange images.

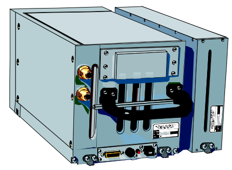
[1] Digital data is represented by a sequence of "bits" with each bit representing one of two values, 0 or 1. An example of digital data is given for voice in the figure. The digital data can be divided into fields as shown for fixed format messages or kept as a string of bits as is done for voice. Each field can be defined to represent numbers (e.g., three bits can represent one of eight values for each numeric of a track number, 000-0, 001-1, 010-2, 011-3, 100-4, ... , 111-7) or items of information (e.g., for an identity field 000-friend, 001-hostile, 010-unknown, 011-assumed friend, etc.).

JTIDS Class 2



1.56 Ft³
125 Lbs
200 Watts
(F-14, MAOC, ABCCC, E-8, MCE, TAOM, Rivet Joint, F-15C at 390 FS, Submarine)

MIDS



LVT

0.6 Ft³
65 Lbs
200 Watts

FDL

0.6 Ft³
52 Lbs
40 Watts

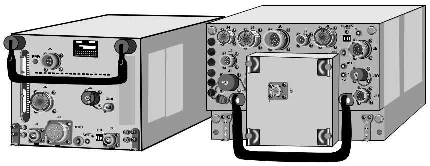
2.4-1 Architecture - Background and Definition of Terms

The concept for a secure, jam resistant tactical data link was developed in the 1970s. The system concept including demonstrations evolved through several names, the last being the Joint Tactical Information Distribution System (JTIDS). In the late 70's the system was formally accepted as a US Tactical Digital Information Link (TADIL J), development of a fixed format message standard was begun and, in the early 1980's, the development of a JTIDS Class 2 terminal was initiated. The JTIDS Class 2 terminal underwent developmental and operational evaluation in 1985-6, and delivery of Class 2 production terminals began shortly thereafter.

Prior to the Class 2 terminal development, a JTIDS terminal was required to provide a secure, jam resistant link between the E-3 and the ground based control units. So in the late 1970s, the JTIDS Class 1 terminal was developed for use on the E-3s, both US and NATO E-3s, and the NATO Air Defense Ground Environment (NADGE) sites. The Adaptable Surface Interface Terminal (ASIT) was developed for use by US ground based control units. The ASIT was designed to exchange JTIDS information with the E-3, and then to exchange that information with the ground based control units using TADIL B. This eliminated the need for modification of the US ground based control units all of which had the capability to exchange TADIL B. Since the TADIL J data link standard was not in place, an interim standard for the JTIDS information exchange was required and that was called the Interim JTIDS Message Specification (IJMS). Subsequently, when the TADIL J format was designed, it was not designed to be compatible with IJMS. Compatibility would have placed undesirable restrictions on TADIL J.

In 1980, NATO decided that they too had a requirement for a more general secure, jam resistant tactical data link. They instituted a study to examine the best characteristics, and the NATO data link system concept was termed the Multifunctional Information Distribution System (MIDS). As part of their study, the characteristics of the US JTIDS system and supporting Class 2 terminals were included. In fact, those characteristics were accepted for the NATO data link system, the data link system was given a formal NATO designation (Link 16) consistent with their normal format, the Class 2 terminal System Segment Specification became the basis for a NATO standardizing agreement (STANAG 4175) for

JTIDS Class 2



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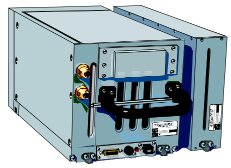
MIDS



LVT

0.6 Ft³
65 Lbs
200 Watts

FDL

0.6 Ft³
52 Lbs
40 Watts

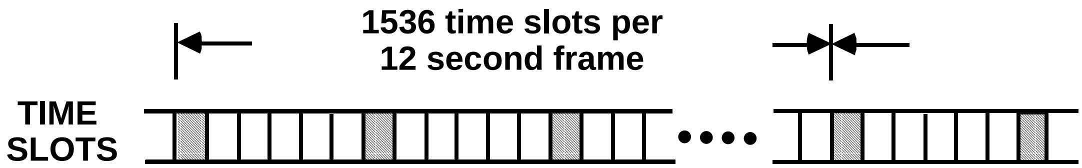
2.4-2 Architecture - Background and Definition of Terms

Link 16 terminals, and the TADIL J data link standard (now termed MIL-STD-6016) became the basis for a NATO standardizing agreement (STANAG 5516) for the Link 16 data link system. In addition, in 1986, five nations (US, France, Italy, Spain and Germany) agreed to develop a MIDS Low Volume Terminal (LVT), a next (after the JTIDS Class 2 terminal) generation terminal. US participation was limited to the Navy.

The MIDS LVT was quite far along in its development when, in the mid 1990s, the US Army and US Air Force joined the effort requesting variants of the MIDS LVT to suit their requirements. The Air Force MIDS variant is termed the Fighter Data Link (FDL) terminal.

The NATO term for the data link system, Link 16, is becoming the world-wide standard. The TADIL J message standard, and the JTIDS Class 2 terminals and MIDS terminals (i.e., the LVT, Army variant and Air Force FDL) all support the Link 16 system.

The waveform used by the JTIDS Class 2 and MIDS terminals is compatible with that used by the earlier JTIDS Class 1 terminal, so both types of JTIDS terminal and the MIDS terminals can coexist in Link 16 networks. However, since IJMS is not compatible with TADIL J, platforms newly implementing with TADIL J would generally have been unable to exchange data with the platforms already equipped with Class 1 terminals. To solve this problem, some Class 2 terminals and the MIDS terminals were made bilingual, able to pass either IJMS or TADIL J messages. Of these, all but the E-3 and MCE Class 2 terminals are translating bilingual terminals. The translating bilingual terminals receive TADIL J messages from the host platform and translate them to IJMS for transmission on the network for receipt by Class 1 terminal equipped platforms, and receive IJMS messages from the network, translate them to TADIL J, and send them to the host platform. Since TADIL J is a more robust message standard, the translations aren't transparent, but they have proven to be a good solution until the Class 1 JTIDS terminals and IJMS are replaced. The E-3 and MCE Class 2 terminals are bilingual pass-through terminals, not a translating terminals. The E-3 already exchanged IJMS when updated to exchange TADIL J, and so the flight processor can exchange either or both concurrently, and the MCE was intended to be a concurrent operator. A translating terminal was not required by either platform.



2.5 Architecture – Time Slot Assignments

Time slots are assigned to a network participant in blocks. The largest block which can be assigned is 512 slots per 12-second frame[2]. This represents one third of all time slots[3]. The three blocks of 512 s/f which comprise all time slots are called sets and are named A, B and C. Available block sizes are reductions from 512 s/f in powers of two (e.g., 256 s/f, 128 s/f, 64 s/f, 32 s/f, 16 s/f, 8 s/f , 4 s/f, 2 s/f, 1 s/f, ½ s/f, ¼ s/f, $^{1}/_{8}$ s/f, $^{1}/_{16}$[4] s/f). For example set A is comprised of two blocks of 256 s/f, four blocks of 128 s/f, eight blocks of 64 s/f, etc. For each time slot block the time slots are distributed evenly in time. The time slots for each set represent one third of all time slots, and each would provide a time slot every three slots. A large block of 256 s/f represents one sixth of all the time slots, and the block would provide a time slot every six slots as shown in the figure. To assign a time slot block to a terminal it is necessary to specify the block size (e.g., 256 s/f) and a starting slot identifier (e.g., A-0 for the first of two blocks comprising set A) of the block being assigned[5].

Having the slots in a block distributed in time is important because the interslot spacing will not only determine the amount of data which can be transmitted, but the speed with which the terminal can access the network (termed response time). For example, if a fighter was assigned a block of 8 s/f in which to transmit its radar targets, this would provide a time slot every 1.5 seconds[6]. If the pilot designates a target for kill by his/her[7] weapon system this information is carried in the associated radar target and the pilot's wingmen want the information quickly. With a time slot every 1.5 seconds, once sent to the terminal by the fighter the target might wait up to 1.5 seconds for a time slot. This wait time, when added to the processing time in the transmitting fighter's flight processor and in the receiving fighter's flight processor, is moving in the direction of marginal performance[8].

More than one time slot block can be assigned to a platform for its transmissions. Up to three blocks can be assigned to the JTIDS Class 1 terminal for general IJMS transmissions. For example a Class 1 terminal equipped block 20/25 E-3 might be assigned 112 s/f with three blocks of 64 s/f, 32 s/f and 16 s/f. The resulting aggregated assignment no longer has its slots distributed evenly in time (i.e., with a single interslot interval), but they are fairly well distributed. The JTIDS Class 2 terminal and MIDS terminals can be assigned up to 64 time slot blocks. The reason for the large number will be discussed subsequently.

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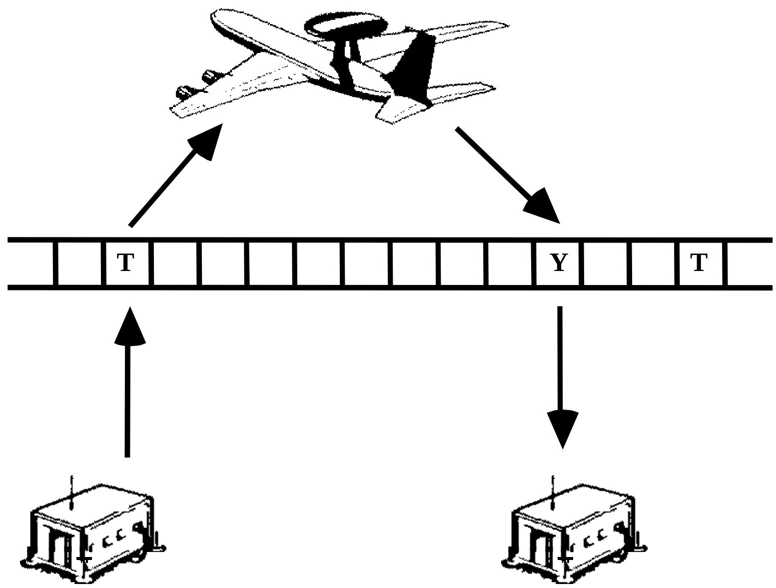
[2] Time slots are normally assigned on a per 12 second frame basis since it is unusual to assign less than one slot per frame (s/f).
[3] Three times 512 s/f is 1536 s/f which is simply 128 slots/second times a 12 second frame.
[4] The JTIDS Class 2 terminal will support assignment of as few as one slot every 3.2 minutes or $^{1}/_{16}$ s/f.
[5] There is a good deal more to time slot identifiers, but it is not necessary for the wing/unit manager.
[6] 1536 s/f ÷ 8 s/f = a 192 slot interslot interval; 192 slots ÷ 128 slots/second = a 1.5 second interslot interval.
[7] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.
[8] Pilot comments indicate a goal of one second for overall response time.

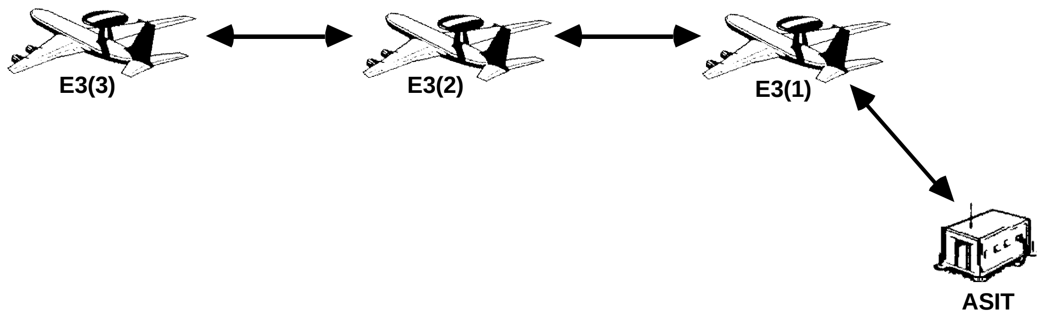


2.6 Architecture – Paired Slot Relay

The most used mode of relay is the simple paired slot relay[9]. It is depicted in the figure. The objective is for the E-3 to relay the messages being transmitted by one ground site to another. The transmitting ground site has been assigned a time slot block of 128 s/f. The figure depicts the 12 slot interslot interval (1536 s/f ÷128 s/f=12 slots). The E-3 is given a relay assignment to receive the information being transmitted in the transmitting ground site's time slot block, hold it for D-1 time slots, and retransmit it in the Dth time slot after reception. D is termed the relay delay, and in this example consists of 9 slots. Transmissions of the relayed information will take place on a time slot block of the same size as the received block, 128 s/f in the example, and offset by the relay delay. The JTIDS Class 1 terminal can relay with a delay of 3 slots or more. The Class 2 terminal can relay with a delay of 6 slots[10] or more. The maximum Class 2 terminal relay delay is 31 slots[11], so the maximum single relay delay for a Class 2 terminal relay is 0.25 sec.

It is possible for some platforms to receive both the direct transmissions and the relayed transmissions. It was recognized that the receiving platform would not wish to receive duplicate messages (e.g., the same air track twice, offset in time by the relay delay). Therefore, when receiving a message, the terminal checks to see if has already been received directly and, if so, discards the relayed message.

[9] Conditional paired slot relay and repromulation relay are also relay modes, but will not be covered in this document.
[10] The Class 2 terminal can actually relay with a delay of 5 slots or more, but 6 slots or more is the specification and many platforms have provided relay assignment validity checking in accordance with the specification which prohibits their use of a relay delay of less than 6 slots. The Navy has good reason to use relay delays of 5 slots, but the rationale for this is disappearing and the trend should be to adhere to the Class 2 and MIDS terminal specifications which indicate 6 slots or more for relay delay.
[11] The JTIDS Class 1 terminal has no practical relay delay limit.



2.7 Architecture – Class 1 Terminal Information Exchange Example

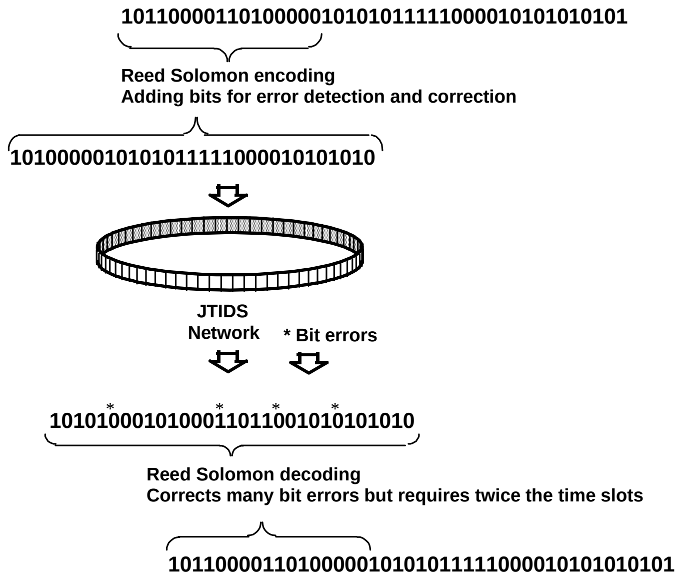
The Class 1 terminal is capable of exchanging IJMS position reports, up to three blocks of general IJMS messages (e.g., air tracks and engagement status), and one channel of 2.4 kbps[12] voice. The rule of thumb when assigning time slots to a Class 1 terminal is to assign 4/3 times the number of air tracks you expect the platform to be reporting. For example, if we assign 128 s/f for general IJMS transmissions we can expect the unit to be able to report tracks on up to 96 entities at the nominal 10 second track reporting interval associated with IJMS. More tracks can be reported, but the reporting interval will lengthen, proportionally[13].

In the figure above we depict an example operation with three E-3s and one ground site. The ground site is an Adaptable Surface Interface Terminal (ASIT). The ASIT was developed in parallel with the JTIDS Class 1 terminal. It is a shelterized system in which is contained a Class 1 terminal, processor and TADIL B modems and encryption equipment. TADIL B is an existing point-to-point Tactical Digital Information Link (TADIL). The ASIT is intended to receive information in a JTIDS network and to forward that information out onto TADIL B, and visa versa. The ASIT was used during Desert Storm to provide the Air Operations Center (AOC) at Riyhad with an air picture much as shown above with the ASIT linked to the AOC via TADIL B.

In this example, the intent is for all participants to exchange, and contribute to, a common surveillance picture. Each participant will be assigned 128 s/f for all its IJMS transmissions which will support the reporting of an IJMS position and status report every 12 seconds, 95[14] air tracks at a 10 second reporting interval, plus track management messages and engagement status. Relay will permit all participants to receive each other's surveillance information. In addition, a coded JTIDS voice channel is desired with relay such that the ASIT, E3(1) and E3(2) can exchange voice and the E3(3), E3(2) and E3(1) can exchange voice. E3(3) will be unable to talk to the ASIT. Information will have to be passed along manually (e.g., ASIT tells E3(1) and E3(2), and then E3(2) tells E3(3)).

Voice coding is discussed next.

[12] Kilobits per second (kbps) is the voice coder digital data rate
[13] For example, 50% more air tracks at a 50% longer reporting interval
[14] ¾ x 127=95 since one s/f of the 128 s/f is being used for an IJMS position and status message.



2.8 Architecture – Voice Coding Options

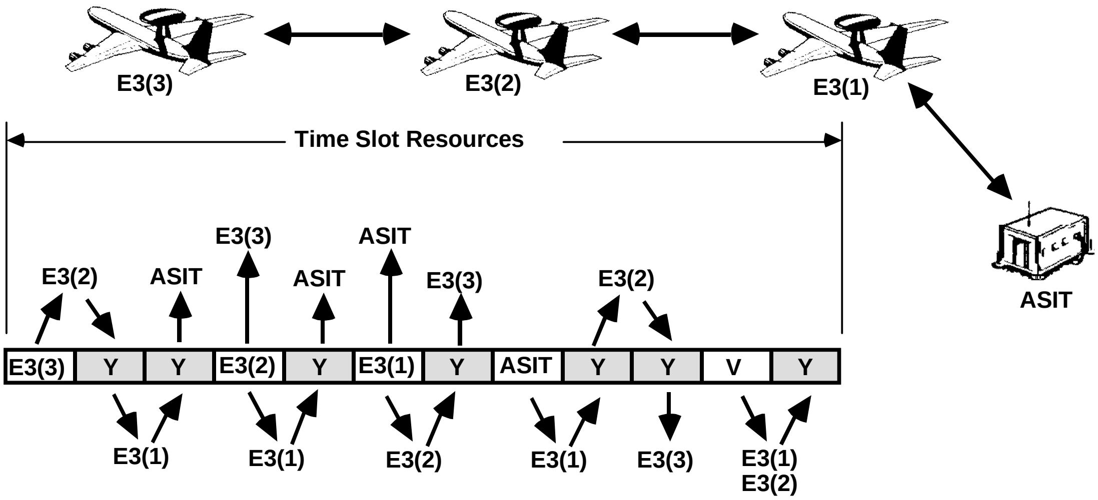
The Class 1 terminal provides a single channel of digitized voice with a 2.4 kbps rate. However, it provides a coding option, and that is described here.

The voice coder receives the voice signal and digitizes it (i.e., creates a stream of bits). The bits are parsed into time slots and transmitted on the network. They are received by the receiving terminal and the voice coder recreates the voice signal from the bit stream and sends it to the host for use via speaker/headset. Along the way, noise can provide bit errors in the received bit stream. These errors will corrupt the reception of the voice signal created by the voice coder. To reduce the number of bit errors and improve the received voice quality, the voice can be exchanged using Reed-Solomon coding.

With Reed-Solomon coding, the digitized signal is passed thorough a special coding algorithm which, in effect, adds many parity bits. For JTIDS coding each 15 bits of basic data is expanded to 31 bits (i.e., an equivalent of 16 parity bits). The coded bit stream is then transmitted on the network where bit errors may take place. However, the received bit stream is then passed through a decoding algorithm which detects and corrects bit errors and missing bits. This Reed-Solomon coding improves the resulting voice signal reception in the presence of noise.

When a network is designed, the designer must specify whether or not the voice is to be coded. Reed-Solomon coding is not an option for fixed format messages. They are always coded. Coded voice exchanges take twice the number of time slots as noncoded exchanges in order to carry the parity bits. So there is a price to pay in improved voice quality, and that is network capacity. The Class 1 terminal requires 128 s/f for coded voice and 64 s/f for uncoded voice. Uncoded voice has been used successfully between C^2 units during the Gulf war. However, it is not acceptable for fighter use. For fighters we use coded voice.

The voice capability of the JTIDS Class 2 terminal will be covered subsequently.



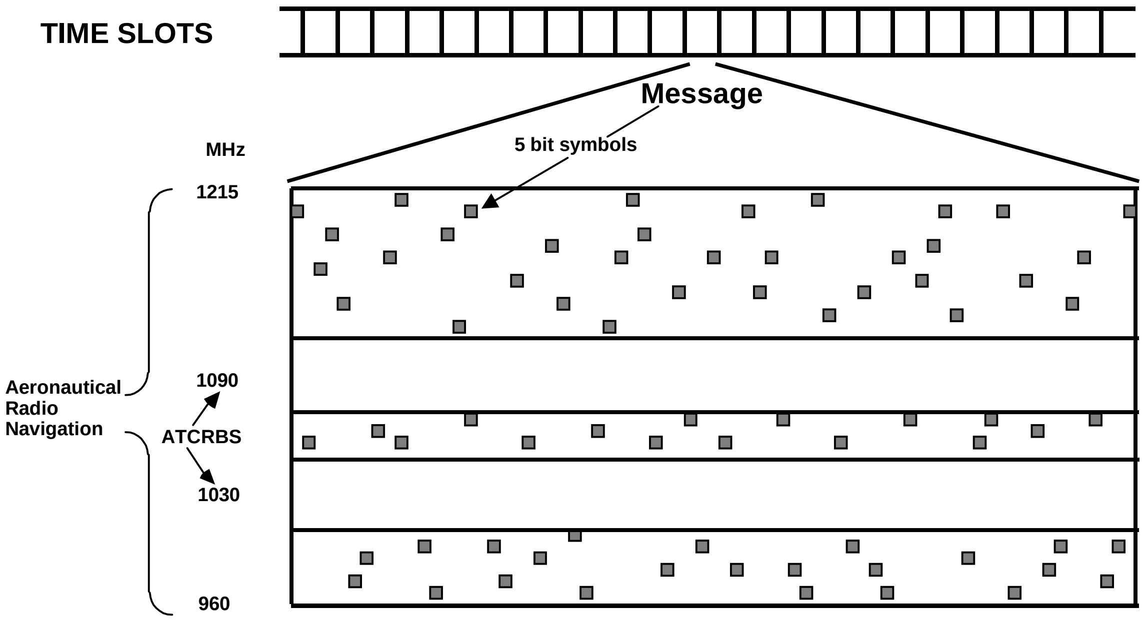
2.9 Architecture – Example Class 1 Network Allocation

The allocation of the example is depicted in the figure via a "time line" chart. Each participant is assigned 128 s/f for IJMS transmissions including their IJMS position report. This is $^1/_{12}$ of all time slots. The time line depicts the allocation of time slots, not their distribution. Remember, time slots in a block are distributed evenly in time so that the block of 128 s/f represents a time slot every 12 slots.

E3(3) transmits its IJMS in the first block to the left. The E3(2) receives from E3(3) for its own use and relays to E-3(1) in the second block from the left. The relay transmissions are shown shaded to distinguish them from original transmissions. E3(1) receives the relay from E3(2) for its own use and relays to the ASIT in the third block from the left. This completes the distribution of data from E3(3). E3(2) transmits its IJMS in the fourth block from the left. E3(3) receives the data for its own use. E3(1) receives the data for its own use and relays to the ASIT. E3(1) transmits its IJMS in the sixth block from the left. The ASIT receives for its own use. The E3(2) receives for its own use and relays to E3(3) in the sixth block from the right. The ASIT transmits its IJMS in the fifth block from the right. E3(1) receives for its own use and relays to E3(2). E3(2) receives for its own use and relays to E3(3). This provides a complete sharing of surveillance and engagement status information. The ASIT then forwards the IJMS picture to the AOC via TADIL B.

Each participant is assigned 128 s/f for coded 2.4 kbps voice and E3(1) and E3(2) are assigned to relay voice. For voice, each participant is not assigned its own time slots as with data. They are all assigned the same slots as transmit slots and the terminal receives when not transmitting anything[15]. This supports a "push-to-talk" protocol. An operator listens to the voice and only talks if no one else is heard talking. E3(1) will relay voice heard from either the ASIT or E3(2), depending on whose talking. So the ASIT, E3(1) and E3(2) can talk together, but the ASIT cannot talk with E3(3). E3(2) will relay voice heard from either E3(1) or E3(3), depending on whose talking. So the E3s can talk together. For the ASIT and E3(3) to exchange information, either E3(1) or E3(2) must pass it along.

[15] In general, terminals receive in transmit time slots which go unused.



2.10 Architecture – Fast Frequency Hop for Jam Resistance

Link 16 shares the radio frequency (RF) spectrum with TACAN/DME[16]. In this band, but excluding the ATCRBS[17] frequencies, 51 discrete frequencies are defined. The messages transmitted in a time slot are then divided up into five bit symbols and each symbol is transmitted on a separate pulse with one of the 51 discrete frequencies. There are 258 such pulses transmitted in a standard time slot and the hopping rate is fast, about 77000 pulses/second.

The hopping pattern is a function of a cryptokey. A receiving terminal which has the cryptokey can synchronize with the pulse stream and just pass the transmitted frequency[18]. However, a jammer without the cryptokey does not know which frequency to jam. It can jam just a few of the frequencies, but the data link has a great deal of bit redundancy such that the loss of many pulses does not effect the accuracy of the information received. The Reed-Solomon coding previously described is an example of bit redundancy[19]. Neither can the jammer learn each frequency by receiving some of a pulse and then jam the pulse due to the short pulse length and the speed of the frequency hop. Therefore, the jammer is left to jam a large part of the band. With the receiving terminal passing only a small fraction of the jamming power pulse-by-pulse, the fast frequency hop forces the jammer to waste most of its power. The ratio of the received jammer power to received signal power which can be sustained while not exceeding a 1% message error rate is termed anti-jam (AJ) margin.

The actual Link 16 AJ margin is classified, but it is quite large. However, it does not make Link 16 jam immune. A jammer which is close enough and radiating enough power, can jam Link 16. However, the AJ margin will bring him close enough to be a prime target.

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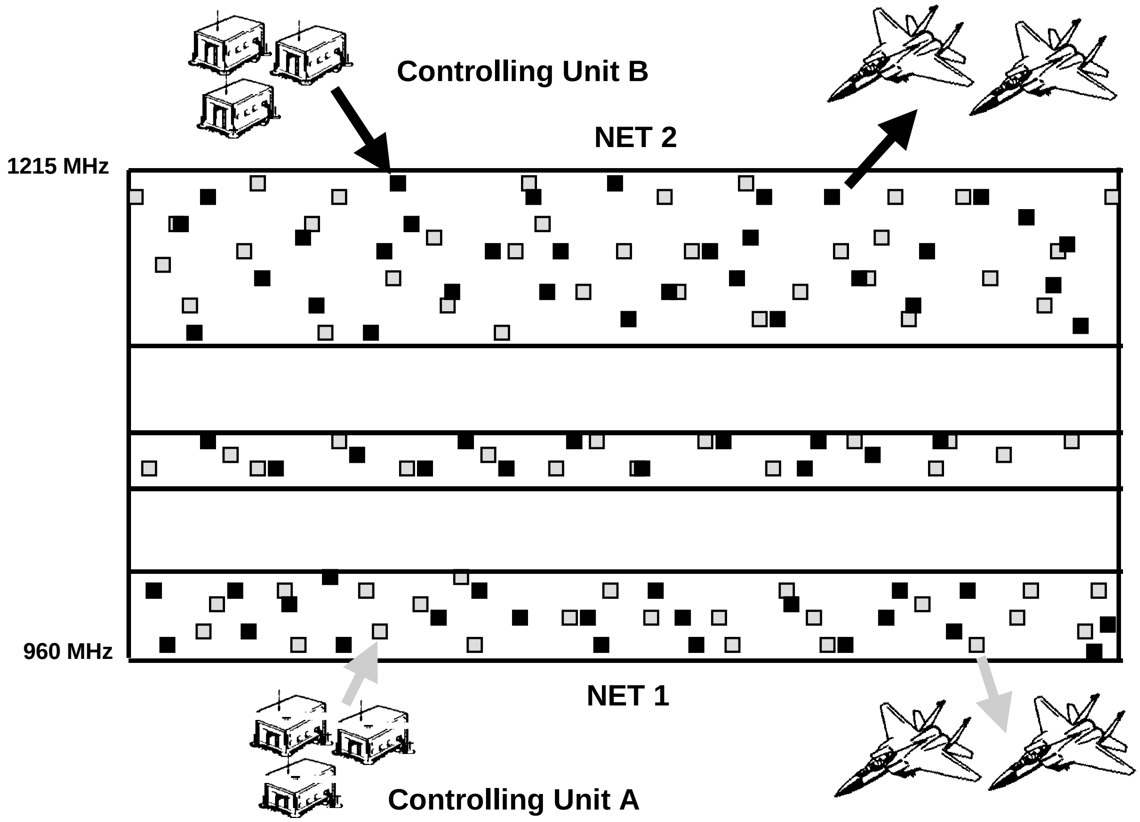
[16] Tactical Air Navigation system and Distance Measuring Equipment.
[17] Air Traffic Control Radar Beacon System
[18] Actually about 3 MHz of bandwidth about the frequency.
[19] A variety of spread spectrum features are used

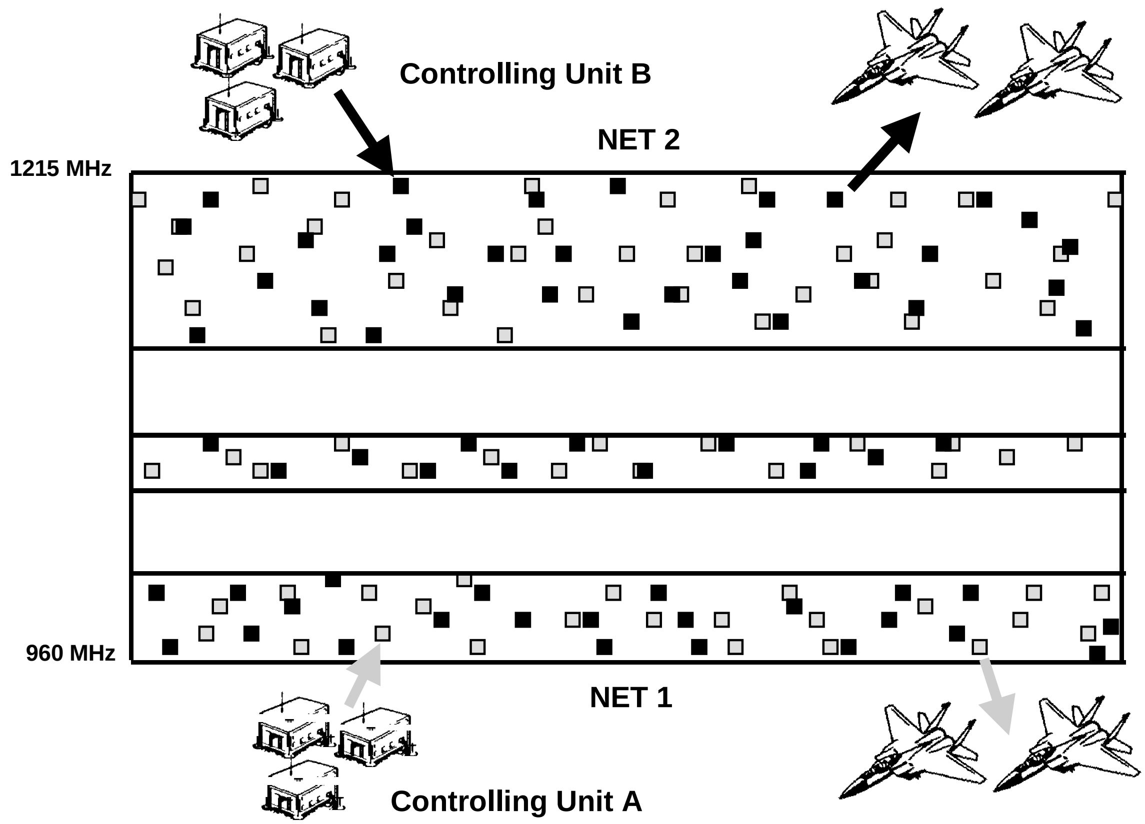


2.11-1 Architecture – Multinetting

In addition to being a function of cryptokey, the frequency hopping pattern is a function of another variable called a net number. This permits different communities of users to use the same time slots to exchange data. An example is shown in the figure. Controlling unit A is controlling his F-15s on net 1 while controlling unit B is controlling his F-15s on net 2. Controlling unit A transmits with the frequency hopping pattern represented by the gray pulses. His fighters are set up to receive the gray frequency hopping pattern pulse-by-pulse, filtering out other frequencies including the pulses of controlling unit B. Similarly, controlling unit B transmits with the frequency hopping pattern represented by the black pulses. His fighters are set up to receive the black frequency hopping pattern pulse-by-pulse, filtering out other frequencies including the pulses of controlling unit A. While the example depicts only two communities, there can be many. There are 127[20] net numbers, 0 through 126. However, while there can be many communities operating on the same time slots on different net numbers (nets for short[21]) and a terminal can operate on different nets from slot to slot, any one terminal can operate on only one net for any given time slot.

Occasionally pulses from two or more multinetted transmitters will collide at a given receiving terminal. What happens will depend on their relative received signal strength and,

[20] The JTIDS Class 1 terminal actually has 128 nets including net 127, but the Class 2 terminal uses net 127 to implement "stacked nets" which will be discussed subsequently.
[21] On occasion a network is referred to as a net. This can cause a good deal of confusion to those just learning about Link 16 and should be avoided. A network is a collection of Link 16 participants all in time synchronization and able to exchange messages. A net is short for net number. A single network can utilize the time slots associated with many nets.

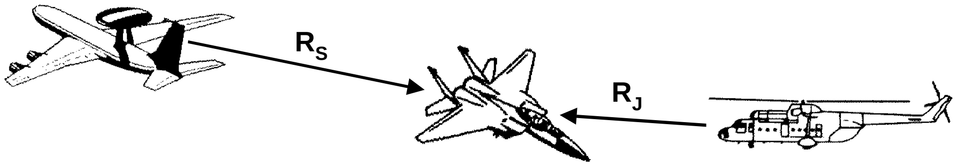


2.11-2 Architecture – Multinetting

given the same transmission power, relative signal strength will depend on relative range. If the terminal from which the receiving unit wishes to receive is closer than the other multinetted unit(s), the desired pulse will normally be received. But if it is further than the multinetted unit(s) the pulse may be lost. The further away the more likely the loss. If an occasional pulse is lost there is so much bit redundancy that there is no effect on received data. But if there are many multinetted units and they are all heavily using their time slots and the terminal from which a receiving unit wishes to receive is further away than many of the multinetted units, the multinetting can impact on the reception. The impact will begin with a loss in jam resistance[22], then the messages will begin to be lost even with no jamming.

There are so many factors involved in assessing the impact of multinetting that a simple rule of thumb can be misleading. However, analyses[23] indicate that if the terminal from which a receiving unit wishes to receive is ten times further away than the other multinetted units, then the unjammed message error rate will grow to 1% as the number of multinetted units transmitting is increased to 15 nets. This 10 to 1 unfavorable range ratio is quite extreme, but an example scenario would be one with fighters close to the forward edge of the battle area and an E-3 150 to 200 nm back, with Army units close to the fighters and multinetted over the E-3 to fighter control channel. As the range ratio lessens, the number of nets which can be sustained increases and vice versa.

[22] Which will not be known to the user until jamming occurs.
[23] This is for the single pulse waveform, the most susceptible to such interference, and so this is a conservative estimate. Single and double pulse will be discussed subsequently.



2.11-3 Architecture – Multinetting

Anti-jam margin[24] is normally measured in decibels (dB[25]). With a 10 to 1 unfavorable range ratio, the use of 14 nets will result in an anti-jam (AJ) margin against a full-band white noise jammer which is 2.5 dB less than that without multinetting, and that loss in AJ is reduced to 1 dB as the number of nets in use is reduced to 8.

It is useful to look at the operational impact of this loss in AJ margin[26] which we'll define as ΔAJ, a positive number. In the figure we have an F-15 approaching the forward edge of the battle area and facing a heliborne jammer. The F-15 wishes to receive situational awareness from an E-3 in the rear. Range to the jammer is R_J (nm) and the range to the E-3 (i.e., the signal source) is R_S (nm). A loss in AJ will have the following impact on the relative ranges to the jammer or signal sources. The 0 subscript denotes the nominal values without the loss in AJ. If $R_S=R_{S0}$ (i.e., we hold the range to the E-3 constant), then $R_J=R_{J0}\text{x}10^{\Delta AJ/20}$, and if $R_J=R_{J0}$ (i.e., we hold the range to the jammer constant), then $R_S=R_{S0}\text{x}10^{-\Delta AJ/20}$.

For an example, suppose there is no multinetting and we have an F-15 near the forward edge of the battle area who wishes to receive from an E-3 which is 150 nm back (R_{S0}=150 nm) and can tolerate a jammer of some power proceeding to within 75 nm of the F-15 (R_{J0}=75 nm) before it experiences a 1% received message error rate (MER). Now suppose that we add 7 nets with multinetted terminals all transmitting on the same slots as the E-3 with a 10 to 1 unfavorable range ratio (i.e., all 7 transmitting terminals are ten times closer to the F-15 than the E-3). This will reduce AJ by 1 dB (i.e., ΔAJ=1 dB). If the F-15 stays 150 nm away from the E-3, the jammer need only proceed to within 84 nm of the F-15 to cause the MER to exceed 1% rather than the nominal 75 nm without multinetting (i.e., $R_J=75\text{x } 10^{[1/20]}$=84 nm). The jammer can jam the F-15 from further away than it can without this very unfavorable multinetting, but not much further away. As the number of nets increases to 14, the jammer range increases to 100 nm. Its harder to kill the jammer, but the likelihood of such a large number of transmitters all with a very unfavorable range ratio is very low.

If the terminal from which a receiving unit wishes to receive is closer than the other multinetted units, then the number of nets which can be employed with no effect on the reception, both with and without jamming, is very large (i.e., well over 50). Actually this is a more normal situation than having very unfavorable range ratios. So in practice we see a rule of thumb on the maximum number of nets being cited as up to 20 nets[27].

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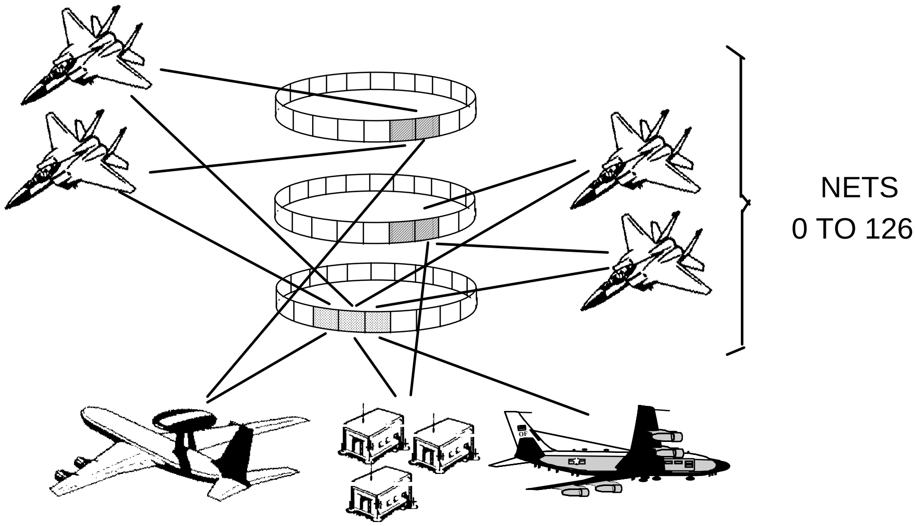
[24] The ratio of the received jammer power (J) to received signal power (S) which can be sustained while not exceeding a 1% message error rate is termed anti-jam (AJ) margin ($J/S|_{1\%}$).

[25] AJ (dB) = 10 log $J/S|_{1\%}$

[26] This also will be used subsequently to discuss other losses in jam margin.

[27] This subsection, although somewhat technical, provides some insight into this rule of thumb.



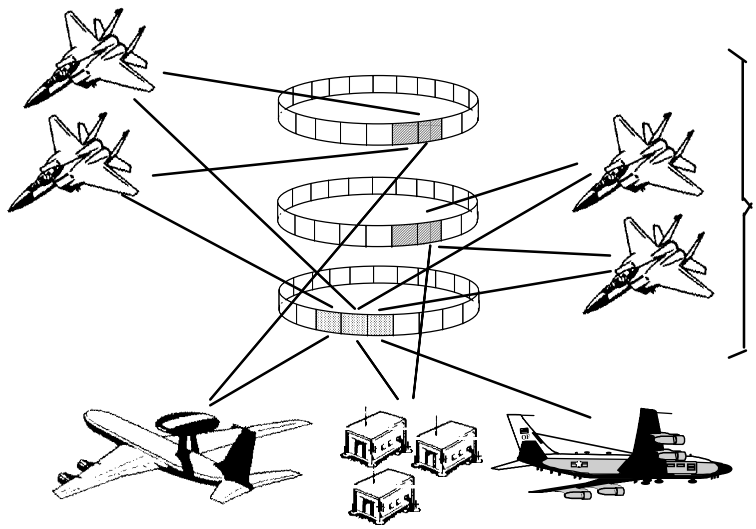
2.12 Architecture – NPGs in Support of Multinetting

For the Class 1 terminal, transmission assignments are made for IJMS position reports[28] and then all other IJMS messages[29]. However, in order to take advantage of the multinetting capability of Link 16 as provided in the Class 2 and MIDS terminals, TADIL J messages are grouped by function and then time slots are assigned to each function. This is depicted in the figure for two such groupings, surveillance and control. The functional groupings are called network participation groups (NPGs). The surveillance NPG is comprised of track reports (air , ground, surface, ...) and track management messages. The control NPG is used by controlling units to issue assignments to their fighters and by their fighters to acknowledge the assignments and report on the status of their engagement.

The figure shows the E-3, CRC and Rivet Joint all exchanging surveillance in the dotted time slots on net 0. The F-15s receive the surveillance picture. So all terminals are operating on net 0 for the surveillance time slots and there are no multinetting opportunities for these slots[30]. However, it also shows the CRC controlling its fighters on net 1 while the E-3 is controlling its fighters on net 2 using the same time slots. This is possible since the E-3 and its fighters and the CRC and its fighters represent two distinct communities.

If there were not NPGs and the surveillance and control messages were transmitted in a single “all TADIL J messages” set of time slots, the above multinetting could not take place. All of the participants wish to exchange surveillance and, since their terminals could not distinguish the slots containing surveillance from those containing control, they would all have to exchange all of the messages.

[28] One time slot block
[29] Up to three time slot blocks
[30] Remember, a terminal can operate on only one net for any given time slot.

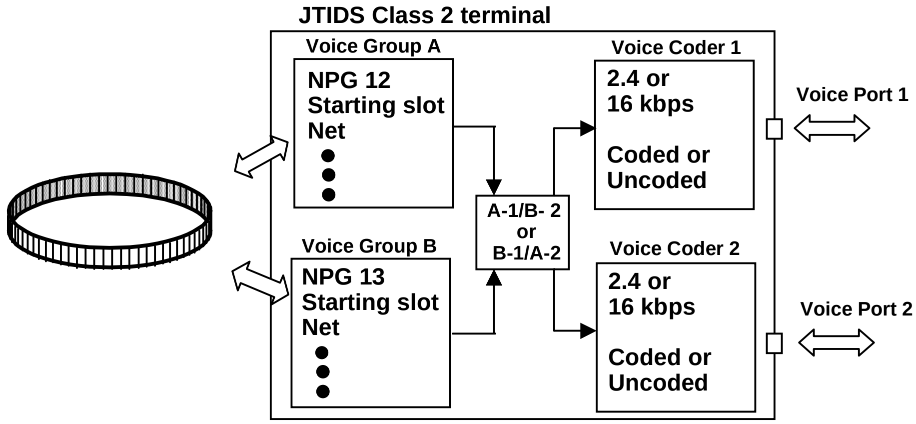


2.13 Architecture – Stacked Nets

Multinetting control would be of limited value if the control nets were fixed during the network design process so the operators could not select control net during an operation. Fighters are required to move from controlling unit to controlling unit during an operation. To support such operator net selection the JTIDS Class 2 terminal is provided a special "stacked net" feature for control and voice[31] NPGs. When stacked nets are designed into a Link 16 network, a "no statement[32]" is entered for the net number of the time slot assignment. This tells the terminal to read the interface to obtain an operator provided net number. For the F-15 that entry is made with a rotary switch[33] on a mode control panel to the left of the pilot in the cockpit. For the E-3 it is made by the communication technician on the control monitor set (CMS)[34].

Since the Class 2 terminal was developed, requirements for operator selection of other NPGs have arisen. How these requirements have been dealt with varies among the services. The F-15 JTIDS Class 2 terminal and the MIDS FDL have been provided with the ability[35] for the operator to select the net number for a fighter-to-fighter NPG[36] (NPG 19) and one spare NPG. The Navy Class 2 terminal and the MIDS LVT have been provided with the ability for the operator[37] to select the net number for any NPG using an approach similar to that used by the F-15 Class 2 terminal.

[31] Voice in the Class 2 terminal will be covered next.
[32] This is done by entering net 127 in the time slot assignment.
[33] Labeled "Mission Channel"
[34] As "Control Net"
[35] This is not done with the same means as are the control and voice stacked nets. Specifically, net 127 is not in the time slot assignment, the starting net is in the assignment which can then be changed by the operator.
[36] This is done in the F-15 via the Fighter Channel selection on the multipurpose color display (MPCD) Menu display.
[37] The wing/unit manager should be aware that the E-2 communication operator can, in fact, select net number for any NPG, and this can and has led to some network difficulties (e.g., when applied to surveillance).



2.14-1 Architecture – JTIDS Class 2 Terminal Voice Capability

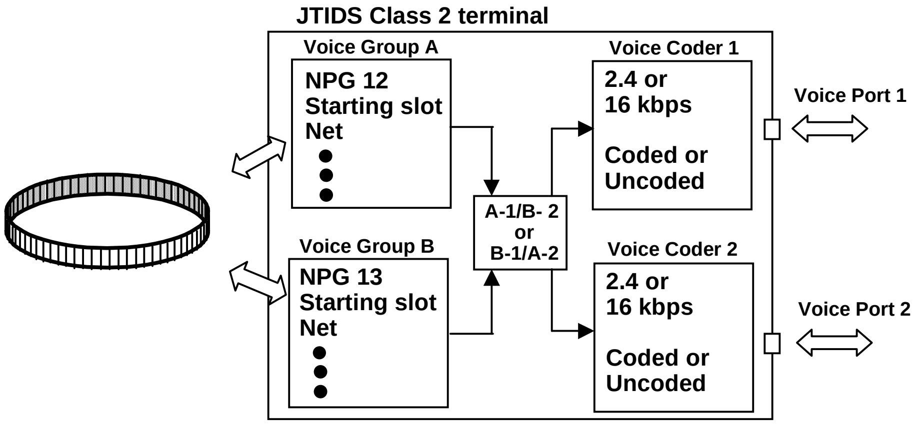
The JTIDS Class 2 terminals have two voice channels called voice group A (NPG 12) and voice group B (NPG 13). An example of the use of both channels would be a two-seat fighter. The pilot could operate on voice group A with his flight members while, at the same time, the weapons surveillance officer (WSO) could operate on voice group B with the controlling unit. Nominally, voice group A would be routed to voice port 1 and into the pilot's headset while voice group B would be routed to voice port 2 and into the WSO's headset. If the opposite was desired, there is a parameter which the pilot or WSO could select which changes the routing so that voice group A goes with port 2 and the WSO, and voice group B goes with port 1 and the pilot. To operate both channels at the same time, time slots have to be assigned to both voice groups.

To support the two voice groups, the terminal has two voice coders. They are associated with the two voice ports. They can independently be set up as uncoded 2.4 kbps, coded 2.4 kbps or 16 kbps uncoded. Uncoded 2.4 kbps voice has proven unacceptable to fighter pilots. 16 kbps voice is very high quality, but takes a good deal of network capacity. There is no option to operate 16 kbps as coded. It would take too many time slots.

The E-3 implements both voice ports, so they can have one operator talking on voice A while another talks on voice B. The set up is nominally voice A on port 1 and voice B on port 2. Voice on port 1 is called radio 4, and voice on port 2 is called radio 5. Radios 4 and 5 are mapped to voice channels A, B, C or D at each console by the radio operator via the audio distribution system. For example, radio 4 could be mapped to channel A and radio 5 could be mapped to channel B. The console operator would then be talking on voice A if selecting channel A, and voice group B if selecting channel B.

The FDL, which will be deployed to most F-15s, does not have a voice capability, so voice is available only to F-15s using the JTIDS Class 2 terminal[38]. The F-15C implements only one voice port, voice port 1. Thus, JTIDS equipped F-15Cs can operate only one voice group at a time. They can select between voice group A or voice group B with the voice group selection parameter (i.e., A-1/B-2 or A-2/B-1) on the multipurpose color display (MPCD) Menu display. However, since the voice coder characteristics are associated with

[38] The 390 FS is currently scheduled to keep their JTIDS Class 2 terminals, even after the FDL is fielded.



2.14-2 Architecture – JTIDS Class 2 Terminal Voice Capability

port not group, for them to operate on either voice group the characteristics of the two groups must be the same (i.e., they can't operate 16 kbps on one and 2.4 kbps on the other). Voice net number selection for the selected voice group is via the Integrated Communication Control Panel (ICCP).

Rivet Joint currently has a partial voice implementation[39]. Like the F-15 they use only voice port 1, and the data link operator (DLO) selects between voice group A ("VOICE A") and voice group B ("VOICE B"). Unlike the F-15 they can use 2.4 kbps on one group and 16 kbps on the other since the DLO can select voice rate for voice port 1, i.e., 2.4 kbps or 16 kbps. The F-15 pilot cannot. Suppose a network was designed with both voice groups, voice group A being coded 2.4 kbps voice and voice group B being uncoded 16 kbps voice. If the crew wished to talk on voice group A, the DLO would select VOICE A (i.e., assign voice group A to port 1) and "2.4 Kbps". The initialization data would set voice port 1 as "coded". If the crew wished to talk on voice group B, the DLO would select VOICE B (i.e., assign voice group B to port 1) and "16 Kbps". The DLO cannot select coding, but the initialized coding does not apply to 16 kbps voice and so the "coded" initialized for voice port 1 applies to 2.4 kbps, but is ignored for the 16 kbps[40]. Of course, if the 2.4 kbps voice is uncoded, coding in the initialization data set is set to "uncoded".

Voice net selection (i.e., "VOICE CHANNEL") is not operative in the current Rivet Joint voice implementation[41]. The crew must operate on a default net established with the Air Force JTIDS Network Design Facility (AF JNDF) when the network is designed. To date net 0 has been used.

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[39] This partial capability must be requested of the Air Force JTIDS Network Design Facility (AF JNDF) when a network request is made since it requires special provisions by the facility to properly set up the Rivet Joint initialization data set.
[40] The inability to select coding in the aircraft does prevent the Rivet Joint from operating in two voice groups if both of the groups are 2.4 kbps with one coded and the other uncoded. In this case, the coding parameter applies to both voice groups and can only be set in the initialization data set to support one of them.
[41] This is scheduled to be made operative in late CY 00 or early CY 01.

Precise Participant Location and Identification (PPLIs)	**NPG 5, 6**
Surveillance	**NPG 7**
Mission Management & Weapons Coordination	**NPG 8**
Control (Stacked)	**NPG 9**
Electronic Warfare	**NPG 10**
Fighter-to-Fighter (F/F) (Stacked)	**NPG 19**
Limited Fighter-to-Fighter (F/F)	**NPG 20**
Voice Group A (2.4 or 16 kbps) (Stacked)	**NPG 12**
Voice Group B (2.4 or 16 kbps) (Stacked)	**NPG 13**
IJMS position reports (P-messages)	**NPG 30**
IJMS surveillance and engagement status	**NPG 31**

2.15-1 Architecture – Some Important NPGs

NPGs are given numeric labels between 1 and 31. There are needline participation groups which are destination based rather than functional message based and assigned numbers 32-512. However, they are used by the Army and not by the Air Force, and so will not be discussed further here.

Transmit time slot assignments must be made to each NPG on which a participant is intended to transmit. The terminal will default receive on one net, but if receptions are to be made on other than the default net, receive assignments for the associated NPGs must be made as well[42]. The total number of time slot assignments which can be made for the Class 2 terminal are 64 blocks. Included in this 64 blocks are relay assignments which have a similar format as time slot blocks. It is not unusual for a Class 2 or MIDS terminal to require 30 to 40 time slot block assignments. The significance of this will become apparent subsequently when the specification of time slot and relay blocks for the terminal is discussed.

The table above lists some important NPGs. TADIL J position and status reports are called precise participant identification and location (PPLI) messages. They are generally created by the navigation function of the terminal, not the host processor[43]. There are two NPGs normally used to produce PPLIs. The Air Force normally uses only NPG 6. The Navy uses NPG 6 for C^2 platform and relayed fighter PPLIs, and NPG 5 for high update rate (HUR) PPLIs exchanged among fighters. Platform status messages which contain such things as fuel and weapons remaining are also transmitted in NPG 6. These messages are provided to the terminal by the flight processor, typically once every 3.2 minutes, and are transmitted by preempting a PPLI time slot. NPG 7 is surveillance represented by air, surface (sea) and ground tracks, ground points and track management messages. NPG 8 represents the exchange of engagement status of fighters and friendly SAMs plus some intra C^2 commands and handover operations. NPG 9 is the digital control of fighters by their

[42] This is also true of the JTIDS Class 1 terminal which can be assigned up to 3 explicit receive blocks for each of up to three nets

[43] Although the host processor provides information used in the creation of the message (e.g., platform type)

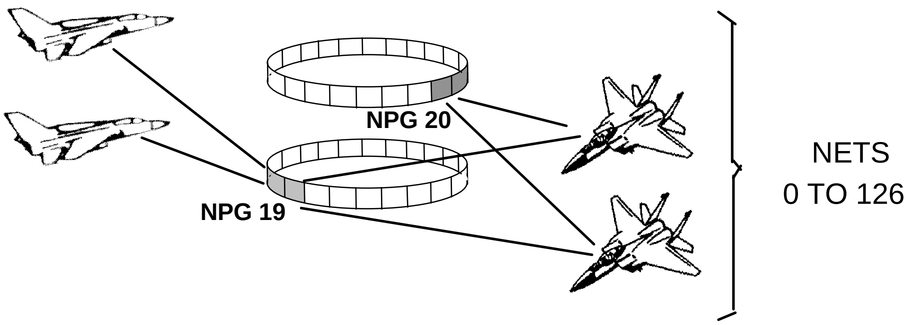
Precise Participant Location and Identification (PPLIs)	**NPG 5, 6**
Surveillance	**NPG 7**
Mission Management & Weapons Coordination	**NPG 8**
Control (Stacked)	**NPG 9**
Electronic Warfare	**NPG 10**
Fighter-to-Fighter (F/F) (Stacked)	**NPG 19**
Limited Fighter-to-Fighter (F/F)	**NPG 20**
Voice Group A (2.4 or 16 kbps) (Stacked)	**NPG 12**
Voice Group B (2.4 or 16 kbps) (Stacked)	**NPG 13**
IJMS position reports (P-messages)	**NPG 30**
IJMS surveillance and engagement status	**NPG 31**

2.15-2 Architecture – Some Important NPGs

controlling unit. NPG 10 is the exchange of electronic warfare (EW) sensor data (e.g., lines of bearing to a jammer or hostile SAM). NPG 10 is for information exchange among EW sources to generate EW products giving actual locations. Once generated the EW products are reported out on the surveillance NPG. NPG 19 represents the exchange of radar targets among fighters. NPG 20 is a second fighter-to-fighter NPG whose use will be described subsequently. NPGs 12 and 13 represent the two voice groups.

NPGs 30 and 31 are concerned with the IJMS/TADIL J bilingual nature of the Air Force terminals. Transmit assignments of NPG 30 will cause the terminal to generate and transmit an IJMS position and status report (termed P-message for short). Assignments of NPG 31 will enable a bilingual terminal to transmit other IJMS messages and receive all IJMS messages. If it is the E-3, the flight processor will generate the IJMS messages (other than the terminal generated P-messages) and send them to the terminal for transmission on the network via NPG 31, and the terminal will pass the IJMS messages received via NPG 31 to the flight processor for processing. The E-3 flight processor processes IJMS and uses a bilingual pass-through[44] terminal. If the host is the F-15 or Rivet Joint, the terminal will receive IJMS messages via NPG 31 receive assignments and translate them into TADIL J messages before sending them to the flight processor. Both the F-15 and Rivet Joint use a translating bilingual terminal. For the Rivet Joint, the nature of its transmissions will depend on an operator setting called "Network Language". If the operator selects "TADIL-J" then the terminal will not translate TADIL J messages to IJMS even if provided NPG 31 assignments. It will only transmit them as TADIL J in TADIL J NPGs. If the operator selects "IJMS", the terminal will send them both as IJMS and as TADIL J if it is given transmit assignments in NPG 31 and the TADIL J NPGs. If it is not assigned time slots in the TADIL J NPGs, the messages will be transmitted only as IJMS. The F-15 only transmits an IJMS P-message and so only requires an NPG 30 transmit assignment.

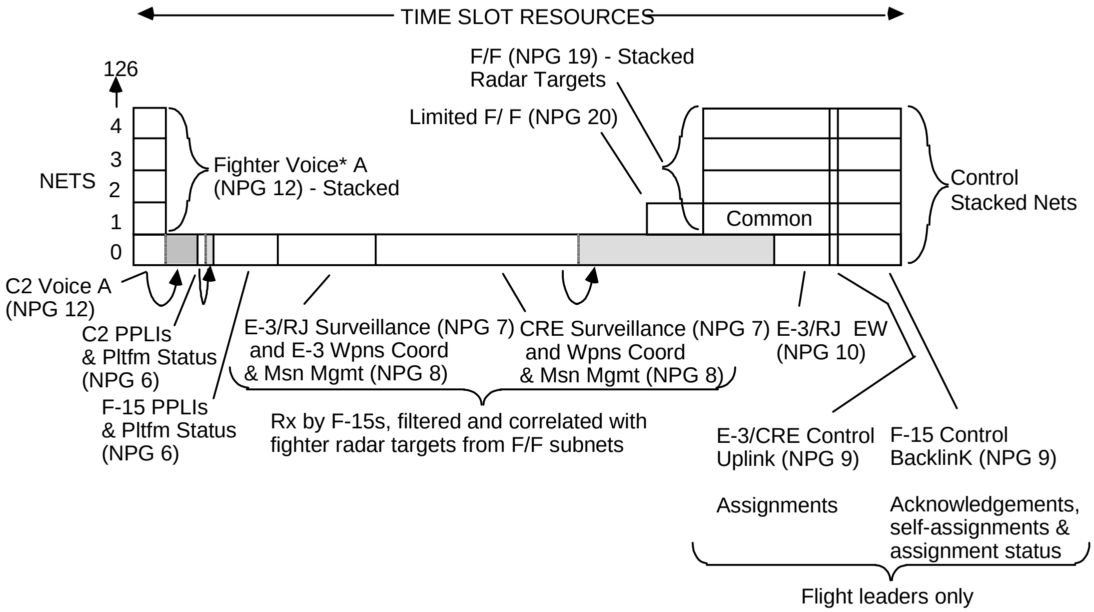
[44] Host generated IJMS is received and transmitted, and IJMS received from the network is passed as IJMS to the flight processor.



2.16 Architecture – Cryptosegregation

Link 16 data exchanges are encrypted, both the waveform and the base band messages. This supports the system's jam resistance and provides information security. The terminal can carry several cryptokeys for this purpose. Cryptokeys are used by the terminal in pairs, one for today and the other for tomorrow, and the terminal's secure data unit can carry up to four cryptokey pairs[45]. The key pairs can be independently applied to various NPG exchanges. For example, the figure depicts the fighter-to-fighter exchanges of a network involving US fighters (e.g., F-15s) and coalition fighters (e.g., Tornados). An allied key pair could be used for all of the network exchanges including fighter-to-fighter NPG 19. This would support fighter-to-fighter exchanges among all fighters. We could then apply a US-only key pair for US-only fighter-to-fighter exchanges on the limited fighter-to-fighter NPG (NPG 20). This would limit these exchanges to the US fighters. Such uses of the data link cryptosegregation capability are being experimented with and considered for operational use by a number of Link 16 equipped platforms.

[45] The details of cryptokey operations are given in a subsequent section.



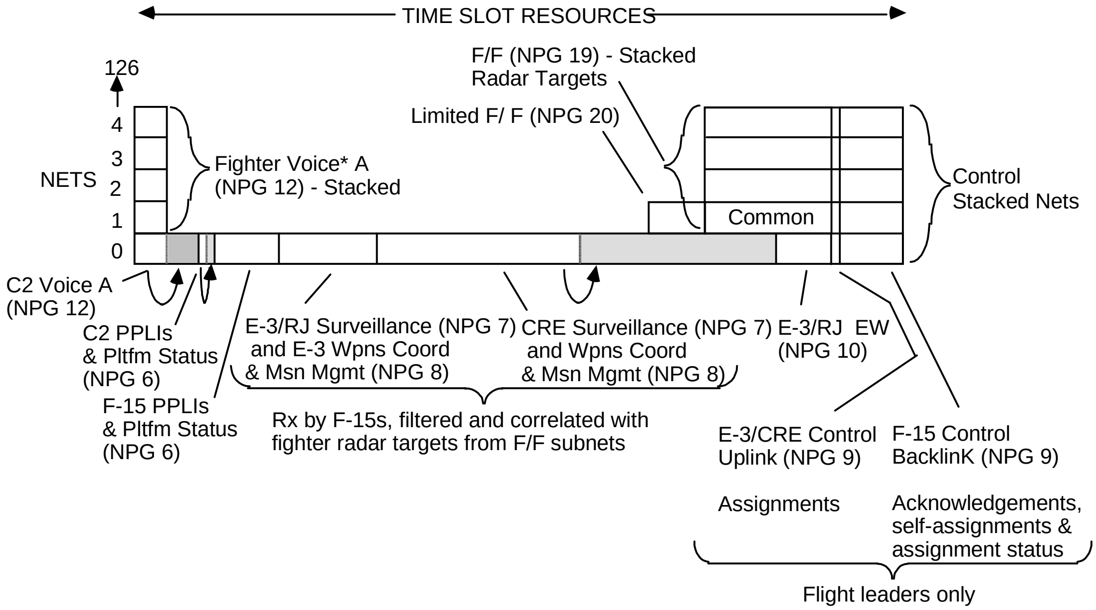
2.17-1 Architecture – Example Air Force Link 16 Network

In the example we have two CREs, one in the forward area and one in the rear. The E-3 will act as relay between the two CREs. Rivet Joint will supplement the surveillance picture created primarily by the E-3 and the two CREs. F-15s are operating in the forward area under the control of the forward CRC and the E-3.

The figure represents a multinetted time line with time slots represented horizontally and nets represented vertically. We begin the description to the left with voice A. This example will not use voice B. Voice A will be used on net 0 for intra C^2 and Rivet Joint (RJ) exchanges, and will be relayed by the E-3 to support exchanges between the CREs. The relay is shown with an arrow from the original transmissions to the relay slots which are shown shaded. On nets 1 and above, flights of F-15s will use voice A for intraflight exchanges, one net per flight. They will talk to their controlling unit via UHF voice, but as a backup can dial voice net 0 and talk to any C^2 unit or the RJ. The voice is coded 2.4 kbps.

Next the C^2 units and RJ exchange PPLIs at a 12 second update interval and the fighters receive. These PPLIs are relayed by the E-3 to support the exchange of CRE PPLIs. The F-15s exchange their PPLIs at a 3 second update interval and the C^2 units and RJ receive. The higher update rate for the fighters is required to provide mutual support in a maneuvering situation. We do not relay the F-15s' PPLIs assuming that they will be at sufficient altitude to be seen by the CREs[46]. The slots assigned for PPLIs also carry platform status messages which preempt PPLIs once every 3.2 minutes. These messages provide fuel and weapons available, etc. The E-3 and RJ exchange their surveillance (NPG 7) and the E-3 transmits its engagement status (NPG 8). The E-3 and RJ transmissions are not relayed since it is assumed that the CREs are within line of sight of both airborne platforms[47]. The CREs exchange their surveillance (NPG 7) and engagement status (NPG 8), and this is relayed. All platforms receive surveillance and engagement status. The F-15s filter tracks

[46] Although this could easily be done.
[47] Rivet Joint does not control fighters and so is not a C^2 unit.



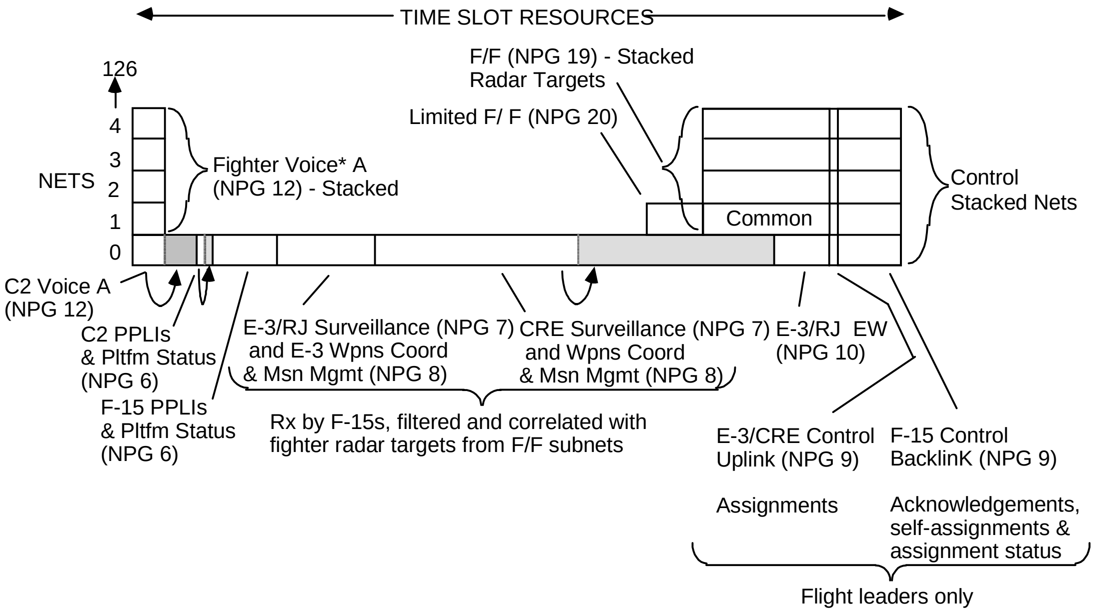
2.17-2 Architecture – Example Air Force Link 16 Network

based on range over range rate (i.e., time to close) giving priority to tracks closing fastest.

Surveillance is exchanged with reporting responsibility (R^2) rules which are intended to place only one track on the network for each entity. One approach to R^2 uses track quality. The surveillance tracks typically contain a track quality estimate made by the reporting unit. The R^2 rules indicate that if a surveillance unit receives a track being reported by another surveillance unit with a track quality which is better than its own (with a specified margin), it should refrain from reporting the track in favor of the unit with the best quality. This is matched with a rule which indicates that if a surveillance unit is receiving a track whose quality falls below its own (with a specified margin), it should begin to report out the track. A second approach to R^2 has each surveillance platform assigned a geographic track production area (TPA). They then report tracks on entities when they are within their TPA. R^2 rules are intended to place only one track on the network for each entity[48].

The E-3 and the RJ exchange EW information to develop EW products for transmission on the surveillance NPG. The CREs do not participate since they do not process EW messages. The main portion of the network ends with the control NPG. There is a control uplink which the C^2 units use to transmit assignments to the fighters and a control backlink in which the fighters transmit their replies. Each C^2 unit and its fighters will operate on a different net (e.g., E-3 on net 0, one CRE on net 1 and the other CRE on net 2). In the Air Force, assignments are made only to the flight lead and apply to the entire flight. An assignment is made against one, and only one, track which is being reported out on surveillance. All flight members will see the pending assignment, but only the flight lead will be able to wilco. When he does wilco the assignment, all flight members will intercept the message and accept the assignment. If another assignment is made and wilcoed, the old assignment is cancelled automatically with a disengaging message from the flight lead. Once

[48] These rules can break down for a number of reasons resulting in duplicate track reports and a confused air picture, but this is a separate topic not discussed here.



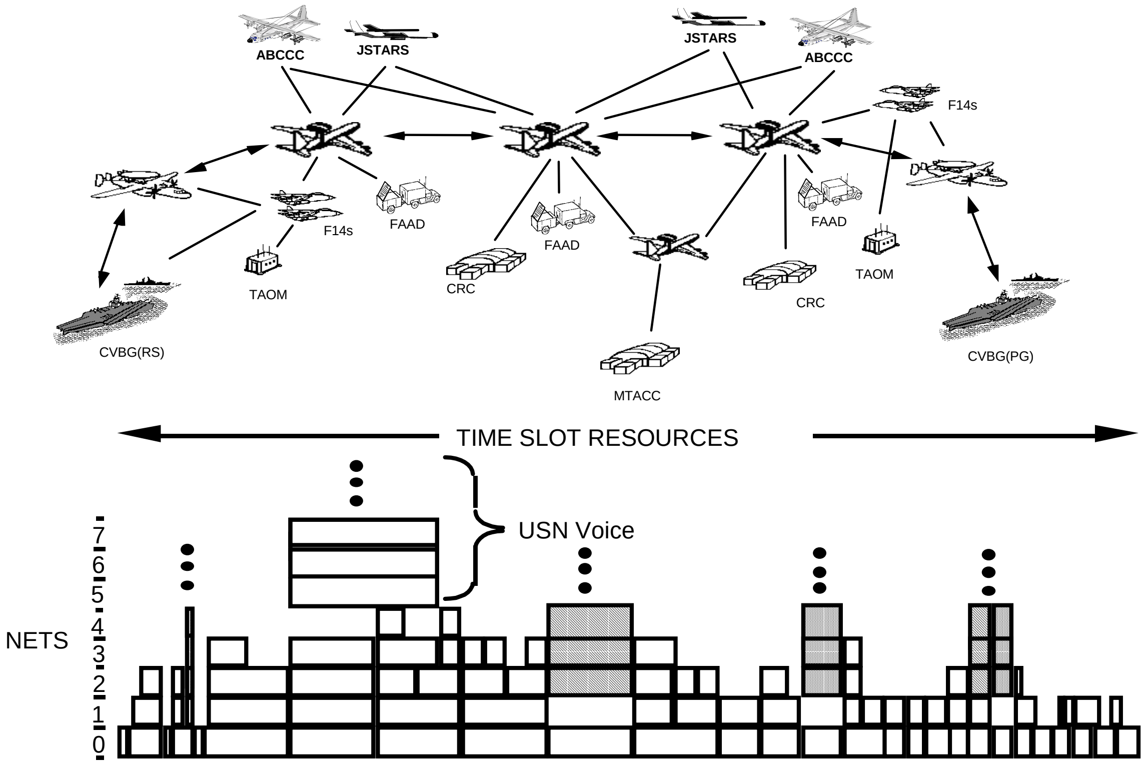
2.17-3 Architecture – Example Air Force Link 16 Network

the flight lead has accepted an assignment, the fighter will report target status on the control backlink every 6 seconds until the engagement is broken or otherwise terminates. A flight lead can also self assign the flight to a reported track[49]. This is reported as target status on the control backlink which informs his flight members and C^2 unit of the self assignment. Very few transmissions occur on the control backlink, only a target status report every 6 seconds by engaged flight leads of flights on the same control backlink.

The F-15s exchange radar targets on NPG 19. All targets generated by a radar tracking mode[50] are reported automatically. There is no automatic R^2 as for tracks on the surveillance NPG. An F-15 receives the targets from other flight members and up to four additional fighters called donors which he can select while airborne. The targets received from the data link are correlated against its own targets and each other. Own targets get priority, off board targets are given first-come first-served priority, and a correlated target picture is created. The correlated targets are then correlated against the surveillance tracks with targets getting priority. In this way the F-15 creates its own correlated air situation display.

The NPG 19 time slots are shown multinetted above the EW exchanges of the E-3 and RJ since the F-15s do not process these exchanges, and the relay of the surveillance and engagement status of the CREs with the assumption that the F-15s are at sufficient altitude to be within line of sight of the CREs and so do not require receipt of their relayed information. All F-15s normally operate on the same fighter-to-fighter net, here shown as net 1, so that they can receive the targets from any other fighter. However, there are circumstances under which different groups of fighters may wish to operate on different fighter-to-fighter nets, and the F-15 implementation supports fighter-to-fighter net selection from the cockpit. NPG 20 time slots are shown only on net 1. They cannot currently be changed by the pilot[51].

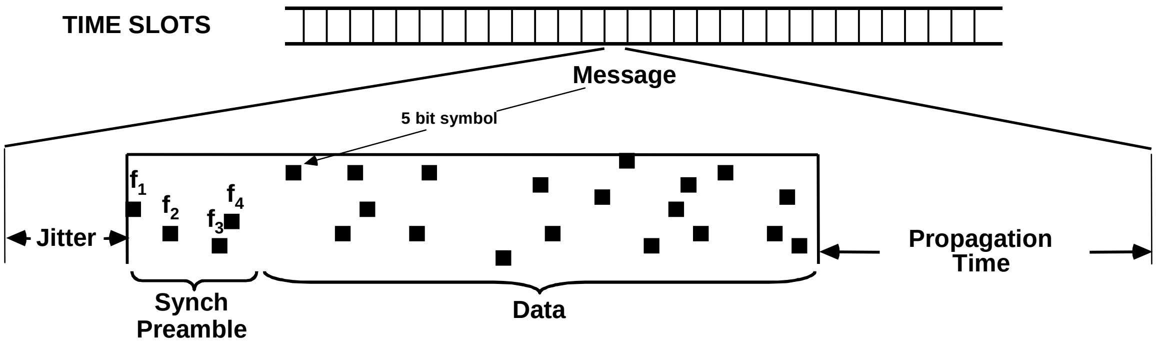
[49] Or self deassign from an existing assignment, either C^2 unit or self assigned.
[50] Track While Scan (TWS) and Single Target Track (STT)
[51] For F-15C OFP Suite 4 they will match the NPG 19 net number.



2.18 Architecture – Example of a Large Scale Link 16 Network

The figure depicts a large scale Link 16 network. As can be seen, rather than just using one main net and then some multinetting for stacked net operations, the main exchanges of this network take place across about four nets (nets 0 through 3) with the stacked nets sticking out of the top of the network. This network is more complex to design than the simple Air Force network, but its operation is quite similar to the operators, and even to the network manager. The use of four nets and the stacked nets are distributed geographically and will cause a negligible effect on message error rate and on jam resistance.

3.0 Modes of Operation



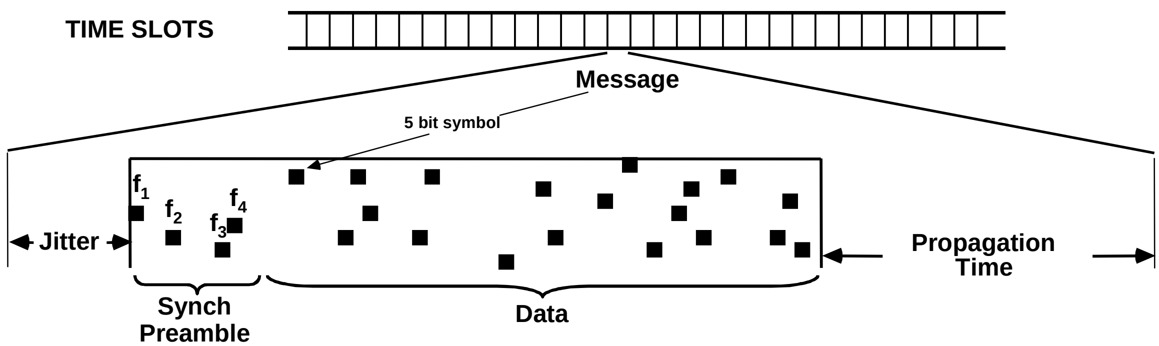
3.1-1 Modes of Operation – Range Mode

A Link 16 message is transmitted as a series of five bit symbols. Each symbol is transmitted with a different carrier frequency (f) which we'll call a pulse. The pulses do not fill the time slot. After the transmission of the pulses, there must be time in the slot for the pulse stream to propagate out to the receiving terminals before the time slot can end and another transmission can begin. Otherwise a distant receiving terminal would be declaring the start of a new time slot in which it could transmit before the pulse stream from the previous slot that it was intended to receive had time to reach it. The propagation time in a standard time slot is sufficient to support a propagation range of 300 nm. However, there is an option to extend that range to 500 nm. This subsection describes that option.

The receiving terminal must synchronize with the incoming pulse stream so that it can filter in (pass) each frequency, pulse-by-pulse. In this way it can exclude the jammer power outside the pulse width[1] to provide jam resistance and from other terminals on other nets to support multinetting. This is done by having the transmitting terminal begin transmitting pulses whose data and hopping pattern are known to the receiving terminal[2], i.e., does not contain real data[3]. The known set of pulses supporting this pulse synchronization function is called the synch preamble. The receiving terminal has multiple receivers, and sets up the receivers to look for the known pattern. In the figure it would set up one receiver for f_1, a second for f_2, a third for f_3 and a fourth for f_4. It begins looking for the pattern at the start of the time slot. Once it finds the pattern, it can begin to filter in (pass) the remaining pulses which will contain the real data.

The transmitted pulses do not begin at the start of the time slot. There is a period of time which varies from slot-to-slot. How it varies is dependent on the transmission security cryptokey. This variable period is called jitter. It is intended to frustrate a special jammer designed to transmit only part of the time[4] such that its jamming pulses reach a receiving terminal just as the synch preamble does. If the jammer can prevent synchronization with

[1] In the frequency domain
[2] To maximize the terminal's ability to receive the pulses.
[3] In practice, not all pulses in the pattern are received by the terminal, so the data must be "throw away" data.
[4] Termed smart partial-time jammer.

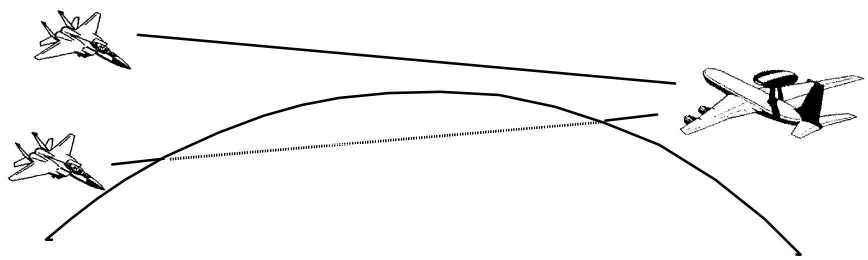


3.1-2 Modes of Operation – Range Mode

the pulse stream, the terminal cannot receive the data. A smart partial-time jammer theoretically permits the concentration of power into the jamming pulse, thus increasing jammer efficiency. In practice, the efficiency gained does not offset the limitations and complexity associated with this type of jammer when compared with a continuous time or a
simple periodic partial-time jammer, and so the likelihood of encountering such a jammer is low. Therefore, the utility of the jitter is thought to be low (but available).

Since it may be desirable to exchange data at longer ranges than 300 nm, and because the jitter is of limited value, the Link 16 terminal supports the tradeoff of jitter for range. 300 nm is considered the normal range, but the terminals also offer an extended range of 500 nm with less jitter. The normal and extended range modes are selected as part of the initialization data set which instructs each terminal how to behave in a Link 16 network.

In a subsequent section, JTIDS/MIDS navigation will be described in some detail, but some discussion is required here. JTIDS/MIDS navigation is critical to some platforms such as the F-15C which does not have and will not receive GPS. A navigating terminal utilizes the reception of PPLIs from other platforms to locate itself accurately relative to those platforms. The navigating terminal measures the time of arrival (TOA) of a PPLI. Since all terminals have a common understanding of when time slots occur, the navigating terminal knows when the received PPLI was transmitted, so with the TOA measurement it can calculate the range to the transmitting terminal. Since the PPLI contains the location of the transmitting terminal, the navigating terminal can get a one dimensional fix on where it is relative to the other network participant. With a succession of such fixes it can navigate in all dimensions. However, to know when the PPLI was transmitted the navigating terminal has to know with which range mode the transmitting terminal is operating. Otherwise it will not calculate an accurate range based on the TOA. To determine which range mode the PPLI was transmitted with, the navigating terminal assumes its transmitted with the same range mode that it itself is using. Therefore, all terminals operating in a network must employ the same range mode, otherwise JTIDS/MIDS navigation will not work. Range mode is selected by the network designer when a network is designed and the selection parameter is distributed as part of the initialization data sets which instruct the terminals how to behave in the network. Some platforms permit the communication operator to alter range mode. This is only to support a coordinated network change. Individual platforms should not change range mode for their own perceived purposes. This is treated further in the navigation section.



3.2 Modes of Operation – Extended Range Mode Limitations

The ability to actually utilize the extended range mode is limited by the fact that the receiver must be within line of sight (LOS) of the transmitter, and LOS depends on the curvature of the earth. The achievable range varies with atmospheric effects because the atmosphere tends to bend the radio waves. A conservative estimate[5] of maximum LOS range (R) from an airborne platform at an altitude of h feet to a platform on the surface is given by

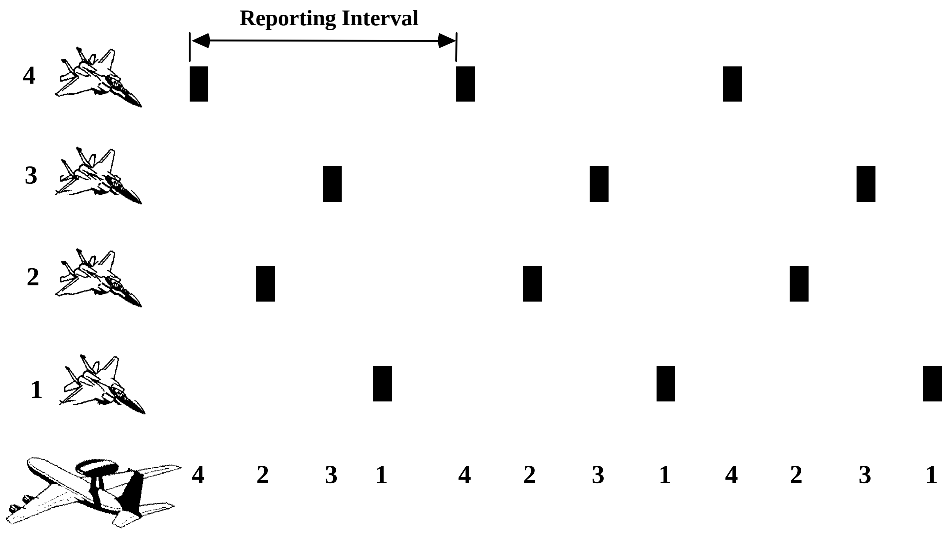
$$R\ (\text{nm}) = 1.1 \sqrt{h\ (\text{ft})},$$

The maximum LOS range between two airborne platforms is simply the sum of the maximum LOS range to the surface of the earth for the two. For example, an E-3 at 29000 ft would be within LOS of a surface platform up to 187 nm away. It could exchange information with another E-3 at 29000 ft up to 375 nm away. So the full 500 nm capability of the extended range mode would not be realized.

There are also synchronization and navigation limitations for platforms operating more than 300 nm from the main body of a Link 16 network when the extended range mode is used. These will be discussed in some detail subsequently in the synch and navigation sections.

Because of these limitations, and the apparent utility of the normal range mode to date, networks are nominally designed with the normal range mode.

[5] 90% of a 4/3 earth LOS range

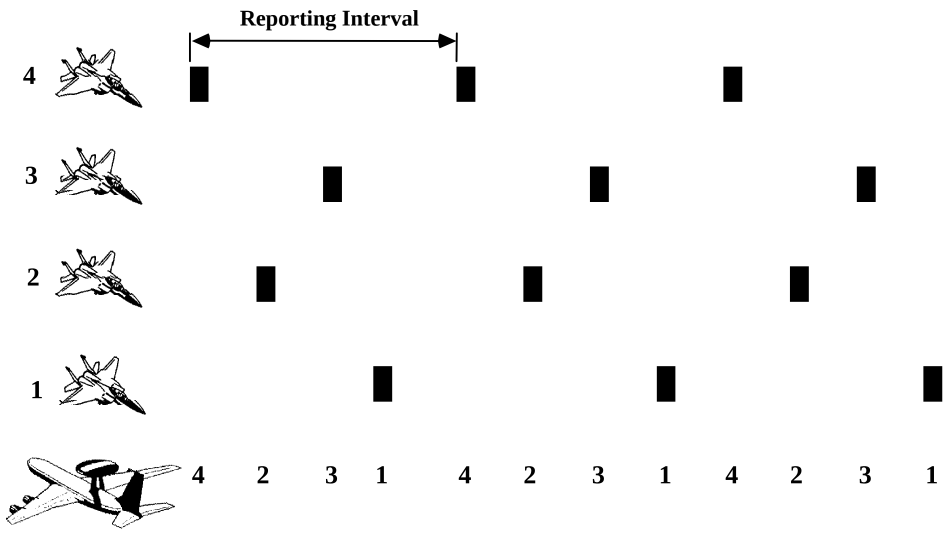


3.3-1 Modes of Operation – Dedicated Access Transmission Mode

The assignment of a single time slot block to each F-15 for the reporting of PPLIs is shown in the figure with an E-3 receiving. We'll assume the F-15s are located in range sequence as shown, i.e., #1, the closest, #2, #3 and #4, the farthest. The assignment would typically be a single block of 4 slots per 12 second frame (s/f) for a 3 second reporting interval. Each F-15 would be given its own unique time slot block. The assignment would be part of the initialization data set for the F-15 which instructs the terminal how to behave in the network. In the figure the E-3 would receive first from F-15 #4, then from #2, then #3, then #1. Then the sequence would repeat with the order of the sequence happenstance based on the network design. This manner of accessing the time slots for transmission is called the dedicated access transmission mode. There is another transmission mode termed contention access[6]. It has certain advantages over the dedicated access mode, and some disadvantages too. This subsection begins a description of both the dedicated and contention access transmission modes.

To support dedicated access each F-15 must use a different initialization data set. It is reasonable to ask what happens if two F-15s use the same initialization data set by accident. This will result in both F-15s transmitting at the same time in the same time slot. The pulses will propagate out from each transmitting F-15. Suppose the two F-15s using the same time slot assignments are #1 and #3. As shown in the figure, the E-3 will receive the pulse stream from #1 first (its closest) and will synchronize with its synch preamble. At that point it will filter in the frequencies from F-15 #1 pulse-by-pulse. The pulses from F-15 #3, which begin to arrive later, will be timed so they are on the wrong frequencies for the filter and will simply be filtered out. They will look no different than the pulses from another platform on another net. So we find that when one or more platforms are transmitting in the same slot on

[6] There is a third access mode called time slot reallocation (TSR), but that is not used by the Air Force at the present time and so will not be discussed here.



3.3-2 Modes of Operation – Dedicated Access Transmission Mode

the same net, a receiving terminal will receive from the closest platform in range sequence[7]. This is termed the capture principle. It is not a very happy consequence for the scenario depicted in the figure since the E-3 won't see F-15 #3 at all! However, it is a useful principle which is used for the contention access transmission mode.

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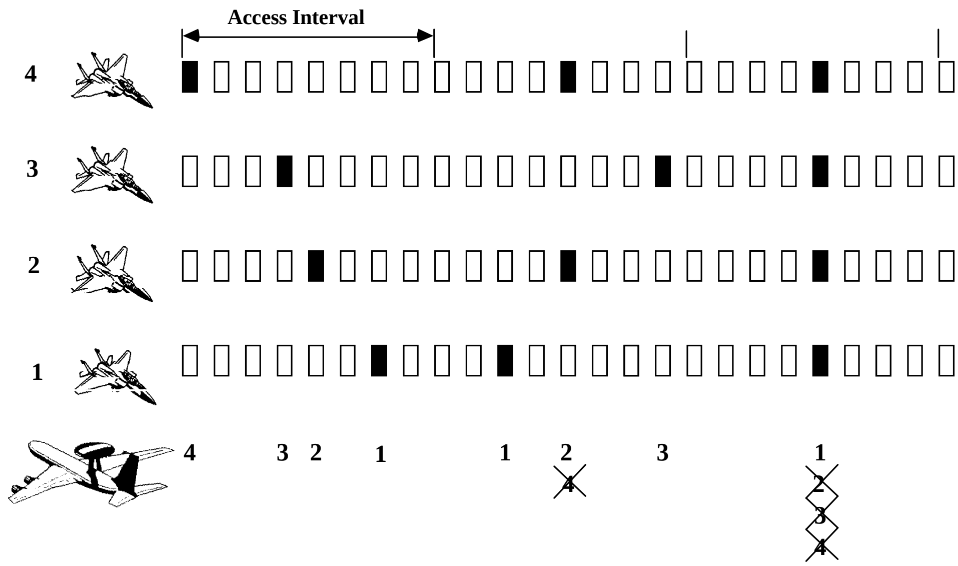
[7] Actually, if the transmitting terminals are within about 300 ft of each other in range to the receiving terminal, the receiving terminal will be unable to synchronize with either pulse stream and so will be unable to receive from either terminal. But this is an unusual circumstance.



3.4 Modes of Operation – Contention Access Transmission Mode

There is an alternative to the dedicated access transmission mode with which a terminal can access the network and it is called the contention access transmission mode. With this access mode the transmitting participants are assigned the same "pool" of time slots. For example, for PPLIs the F-15s might be assigned a block of 64 slots per 12 second frame (s/f). Then, each transmitting participant is assigned an access interval which represents the average rate at which it can actually transmit. The transmitting terminal randomly selects one transmit slot from the pool once per access interval. For example, the F-15s might be assigned a 1.5 second access interval. With a 64 s/f pool this will result in 8 slots per access interval[8]. Then, every 1.5 seconds, the transmitting terminal will randomly select one of the 8 slots to use for a transmission. The result of this is shown in the figure.

During the first access interval we luck out[9]. Each F-15 selects a different time slot in which to transmit and the E-3 receives from all the F-15s. In the second access interval, F-15 #2 and F-15 #4 both happen to select the same time slot. Because of the capture principle, the E-3 will only receive from the closer of the two, F-15 #2. In the third access interval, we get real unlucky[10] and all the F-15s select the same time slot. In this case the E-3 only receives from F-15 #1. Notice that the E-3 will always receive from F-15 #1, will receive from F-15 #2 unless F-15 #1 has selected the same slot, will receive from F-15 #3 unless either F-15 #2 or F-15 #1 have selected the same slot, etc. So the average rate with which the E-3 will receive from any F-15 will depend on its sequence in range, with the average update interval lengthening as the sequence number increases due to an increase in missed receptions. In the example, the average received update interval for the F-15s is 2.2 seconds for #4, 1.9 seconds for #3, 1.7 seconds for #2 and 1.5 seconds for #1. The applications of contention access are discussed next.

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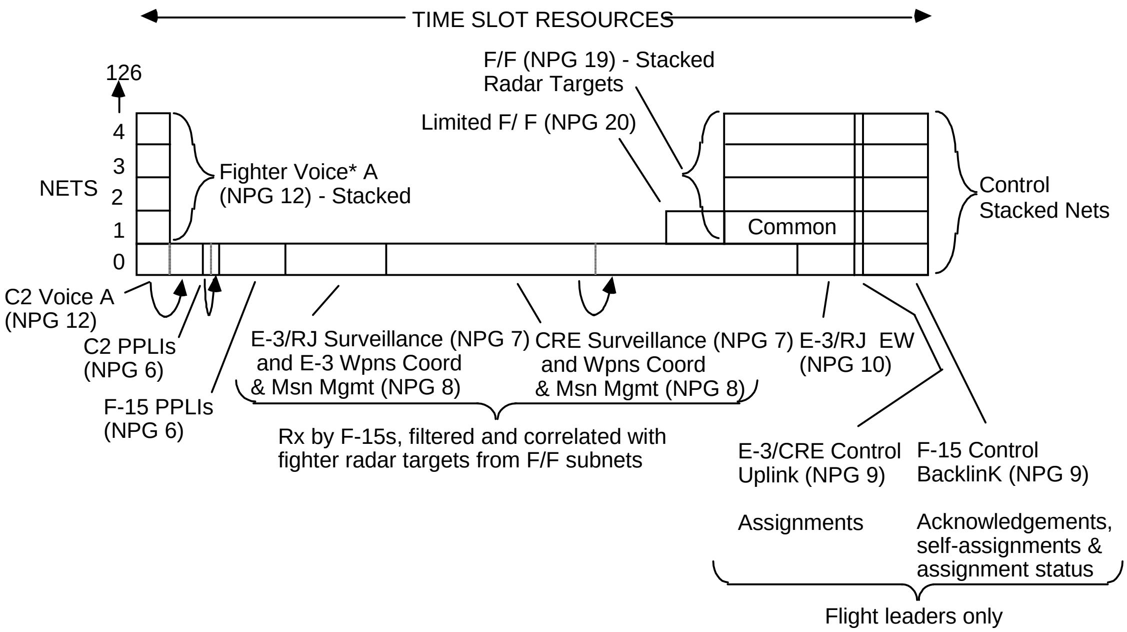
[8] 64 slots ÷ 12 seconds x 1.5 seconds = 8 slots
[9] With the example, the probability of this is about 45%.
[10] With this example, the probability of this is about 0.2%

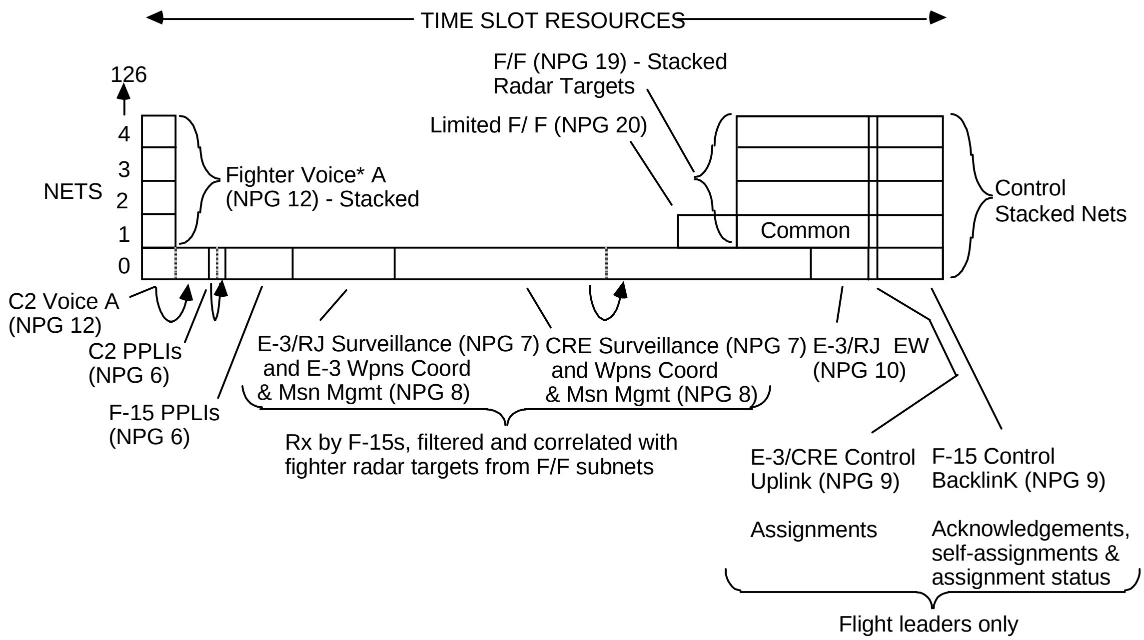


3.5-1 Modes of Operation – Applications of Contention Access

From the figure we see the F-15s will transmit PPLIs (NPG 6), the control backlink (NPG 9) and fighter-to-fighter (F/F, NPG 19 and limited F/F, NPG 20). If dedicated access is used, each F-15 will have its own unique set of time slot assignments. Therefore, each F-15 must use a different set of initialization data, and the pilots have to keep their initialization data sets straight. This could be tough in a wartime environment. While there are a few initialization parameters which must be unique from fighter to fighter such as its identifying track number which is reported in its PPLI, these can be changed from the cockpit. Time slot assignment parameters are too great in number to support manual cockpit entry, and require a trip to the Air Force Mission Support System (AFMSS) by the pilot if he/she[11] has the wrong initialization data set. So, one attraction for the contention access transmission mode is that all the F-15s have the same time slot assignments. The pilots need not be fussy about each using a different initialization data set as is the case with the dedicated access mode since those few parameters which must be unique for the fighter can be easily entered from the cockpit.

A second reason is the efficient use of network capacity. This is best illustrated with the control backlink. With the backlink only the flight leader of an engaged flight is transmitting. It is transmitting target status with a 6 second access interval. Occasionally there is a mission assignment/deassignment to a flight leader, and he will acknowledge. If we were to use dedicated access a likely assignment would be 4 slots per 12 second frame (s/f). This provides a 3 second interslot interval, and once the pilot wilco's an assignment this means the controller might have to wait up to 3 seconds for a slot for the wilco to be returned. The next smallest assignment (2 s/f) would result in up to a 6 second wait and we
judge 3 seconds to be long enough. This 4 s/f assignment must be made to every fighter on

[11] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.

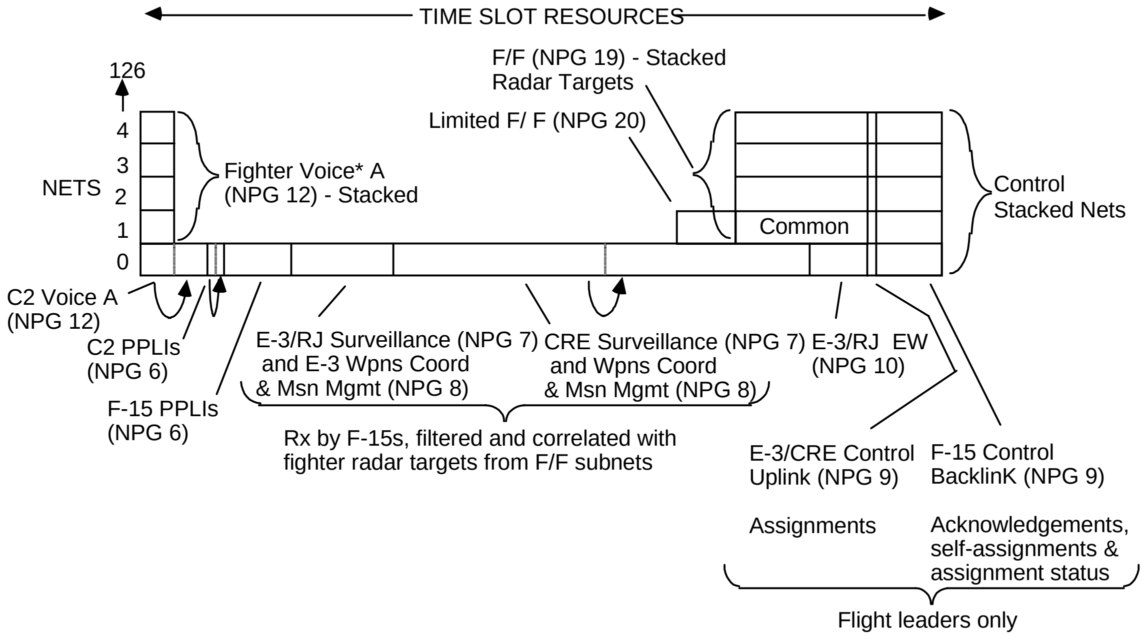


3.5-2 Modes of Operation – Applications of Contention Access

the backlink since the role of flight leader can change while the aircraft are in flight and any flight may be engaged. For up to 5 four-ship flights, this would result in a backlink of 80 s/f.

Assume that with 5 flights, we provide for 3 flights to be engaged at any one time. Thus, up to 3 flight leaders may be transmitting up to 2 s/f of target status on the backlink. Suppose we assign a control backlink of 32 s/f with a access interval of 1.5 seconds. This results in the same link access as the dedicated access (i.e., average of 1.5 seconds with a 3 second worst case). With three fighters engaged, the probability that a fourth flight lead's acknowledgement will be received by the C^2 unit when the flight leader is the most distant in range sequence is about 82%, not so good. But the acknowledgement is sent up to three times by the terminal automatically if it is not received by the C^2 unit, and this increases the probability of reception to over 99%. So the backlink performance is actually quite good with less than half the time slots required of the dedicated access mode. This illustrates that contention access is ideal when applied to NPGs in which the transmitting participants do not all wish to transmit at the same time, and for which transmissions are normally light in volume but require a fast response time. This is just the case for the control backlink, and is the case for fighter-to-fighter exchanges as well.

A third reason for using the contention access mode is that the number of participants who can operate is soft. While the pool is sized to support a certain number of fighters, if it is important to actually operate an increased number nothing catastrophic happens. The contention exchange performance simply degrades somewhat. For example, the average PPLI received update interval would lengthen a bit and the probability of receiving a mission assignment acknowledgement would drop a bit. With the use of dedicated access this is not the case. If all initialization data sets are in use, an additional fighter can only take one of the sets already in use, and the capture principle results in a seriously compromised exchange for the additional fighter and the fighter whose initialization data set he used.

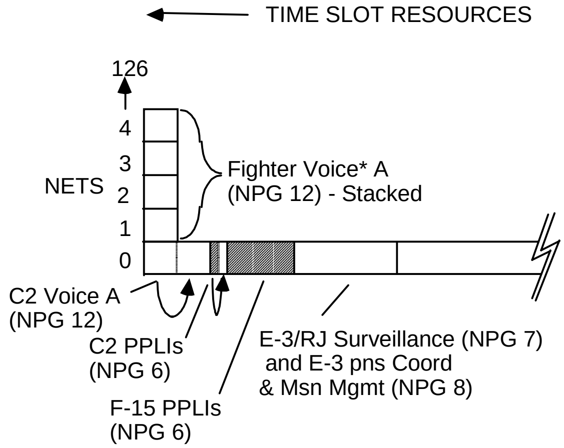


3.5-3 Modes of Operation – Applications of Contention Access

If contention access is so handy, why don't F-15s use it all the time? There are at least two reasons. Link 16 shares the aeronautical radionavigation band. The Federal Aviation Administration (FAA) manages this band and has placed significant constraints on its peacetime use by the Department of Defense for Link 16. This is also true when operating abroad with the constraints determined by the various civil aviation authorities. This topic is covered in some detail subsequently. However, there are concerns that due to the multiple transmissions in the same time slot, contention access may compromise the performance of the radionavigational aids more than dedicated access. Therefore, there are situations under which the F-15s are not permitted to use the contention access mode. This is particularly true for operations abroad, such as to the NATO theater. So the F-15s do not always use contention access because sometimes they can't.

Even when the FAA permits the use of contention access, other constraints can restrict its use. The concept of time slot duty factor (TSDF) will be discussed at length subsequently, but for now consider it the percent of transmit time slots used by each network participant. For example, the contribution of 4 s/f assigned to a fighter for the control backlink with dedicated access represents 0.26%. If contention access is used, an equivalent link access time requires an access interval of 1.5 seconds. This is equivalent to 8 s/f when calculating TSDF even though no one fighter will ever transmit in every time slot for more than a few slots in a row. This doubles the contribution of the control backlink to the TSDF, and this is similar for the fighter-to-fighter exchanges. The sum total of all the individual participant TSDFs in an area is limited by the FAA during peacetime operations. Therefore, the increased TSDF due to the use of contention access, even when contention access is permitted, can dictate the use of the dedicated access mode.

<u>So the wing/unit manager and the combat operators must be prepared to see F-15s operating in contention access sometimes and in dedicated access at other times.</u>



3.6 Modes of Operation – Dedicated Position Reporting Performance

The C^2 units normally transmit their position reports with a dedicated time slot assignment of 1 slot per 12 second frame (s/f). These are either IJMS P-messages or TADIL J PPLIs, or both. Occasionally a P-message will be preempted in favor of the terminal's transmission of a message[12] used for network synchronization. Synchronization will be discussed subsequently, but the rate of preemption is once per 48 seconds, so the P-message reception interval will normally be 12 seconds, but will lengthen to 24 seconds every third interval[13]. PPLIs are normally not preempted for network synchronization messages[14], but they are preempted for platform status messages once every 3.2 minutes. So every 3.2 minutes a receiving unit will see the PPLI reporting interval lengthen from 12 seconds to 24 seconds.

When employing dedicated access, the F-15s normally transmit their IJMS P-messages with a time slot assignment of 1 s/f just like the C^2 units. F-15 P-messages are intended only for use by Class 1 terminal equipped C^2 units such as the block 20/25 E-3s and the NATO Air Defense Ground Environment (NADGE). F-15 flight processors do not process P-messages from other fighters. Like the C^2 units, the F-15s occasionally preempt their P-messages to transmit network synchronization messages.

The F-15s rely on the exchange of PPLIs. F-15s normally transmit their PPLIs with a time slot assignment of 4 s/f. This provides for a received update interval of 3 seconds. However, they too preempt their PPLIs for platform status messages. This is currently at the rate of once every 3.2 minutes. For the F-15 Suite 4 Operational Flight Program (OFP) this is being increased to once every 48 seconds. But right now the received update interval is 3 seconds, lengthened to 6 seconds every 3.2 minutes[15].

[12] Termed a round trip timing (RTT) message

[13] Actually, only the Class 2 terminal preempts only P-messages. The Class 1 terminal uses its general IJMS time slots too, and since there are a lot more of them than P-message slots, preemption of its P-message is unlikely. So this preemption rate is only for Class 2 terminal equipped C^2 units.

[14] There is a separate NPG for RTT exchanges. This will be discussed with network synchronization subsequently.

[15] There is a JTIDS Class 2 terminal problem which currently lengthens these received update intervals to 6 seconds and 12 seconds, respectively when the F-15s are using a special JTIDS navigation mode called relative grid. Navigation will be treated in more detail subsequently. In any case, the FDL does not exhibit the problem and fielding of the Class 2 terminal fix for the 390 FS should be completed by 2002.

Which F-15	Average Received Interval (Seconds)	Frequency (average minutes between occurrence) that intervals exceed: 12 seconds	24 seconds	36 seconds
from 8th	4.0	6.3	Never	Never
from 12th	4.8	2.2	113.9	Never
from 16th	5.7	1.2	24.7	498.2
from 20th	6.7	0.9	9.0	94.7
Access Interval = 3 seconds (Access Code[16] = 7)				

3.7-1 Modes of Operation – Contention Position Reporting Performance

When employing contention access, the F-15s normally transmit their P-messages in a contention pool. The criteria for pool design is that for the most distant F-15 in range sequence which a C^2 unit would be controlling or about to control, the received P-message interval should not exceed 12 seconds more often than 20% of the time. This criteria is similar to the received radar hit probability[17] for a good primary radar. This means that the received interval may exceed 24 seconds no more than 4%[18] of the time, 36 seconds no more than 1%[19] of the time, etc. A P-message pool size of 96 s/f is typical, satisfies this criteria for the 20th F-15 and produces an average received P-message interval from the 20th F-15 of about 7 seconds. Of course the received P-message performance is better for all F-15s closer to the C^2 unit. The performance of this pool is shown in the table.

For PPLIs, the contention pool criteria for the P-messages is retained for C^2 unit reception, but we add a second criteria for fighter reception. Both criteria must be satisfied by the contention pool. For the fighter reception criteria we concentrate on two four-ship flights. The criteria is that when the #1 F-15 is receiving from the #8 F-15 in range sequence, the received PPLI interval should exceed 13 seconds only rarely during a mission, e.g., once every 20 minutes and almost never exceed 25 seconds. A 13 second interval for interfighter use of PPLIs is considered a threshold. The F-15 flight processor will begin to flash the PPLI symbol on the multipurpose color display (MPCD) of the F-15 when the received PPLI interval exceeds 13 seconds. It will purge the PPLI from the display entirely if the update interval exceeds 25 seconds.

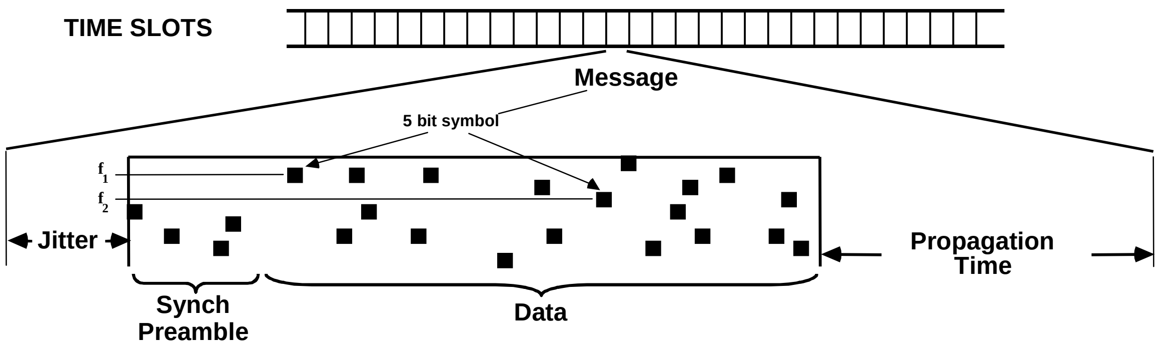
[16] Access code is used to specify access interval in a time slot assignment which uses contention access
[17] Termed radar Probability of Detection (P_d) which is about 80% for a good radar.
[18] $100 \times .2^2$
[19] $100 \times .2^3$

Which F-15	Average Received Interval (Seconds)	Frequency (average minutes between occurrence) that intervals exceed: 6 seconds	13 seconds(f)	25 seconds(p)
from 4th	2.4	2.2	692.3	Never
from 6th	2.8	1	70.9	Never
from 8th	3.1	0.6	17.8	Never
from 10th	3.6	0.4	6.9	946
from 12th	4.1	0.4	3.5	203.6
Access Interval = 2 seconds (Access Code = 8)				

3.7-2 Modes of Operation – Contention Position Reporting Performance

A typical PPLI contention pool is 96 s/f with a 2 second access interval. The performance is shown in the table. The "f" and "p" in the 13 and 25 second interval columns indicate F-15 host display *flash* and *purge* time limits based on the time interval since the last target update. "Never" indicates that the frequency that the received intervals exceed the respective period is approximately 24 hours or greater. This pool exhibits the probability of a 12 second or less reception interval of about 85% for the 20th F-15 away, with an average received update interval of about 7 seconds, and so more than satisfies the C^2 unit criteria for 20 fighters.

Note that to achieve a similar performance for 12 F-15s using dedicated access would take 4 s/f per F-15 and a total of 48 s/f, half the number required of the example contention pool. When all contention transmitters must be received and all the assigned slots are always filled, the contention access mode is less efficient than the dedicated access mode. This is the case for small PPLI contention pools. However, for large pools applied to large networks in which no one network participant needs to receive effectively from all participants, contention access once again becomes efficient, even for PPLIs. Such a scenario would be one covering a large area such as in the Gulf region, with perhaps as many as 60 fighters being supported, only the closest 20 of which are of high interest to any one controlling unit and only the closest 8 to 12 of which are of high interest to any one fighter. The example contention pool is suitable for this scenario with no change, but using dedicated access would require 4 s/f for each of 60 fighters for a total of 240 s/f, 2½ times the 96 s/f required by the contention pool.



3.8-1 Modes of Operation – Message Packing

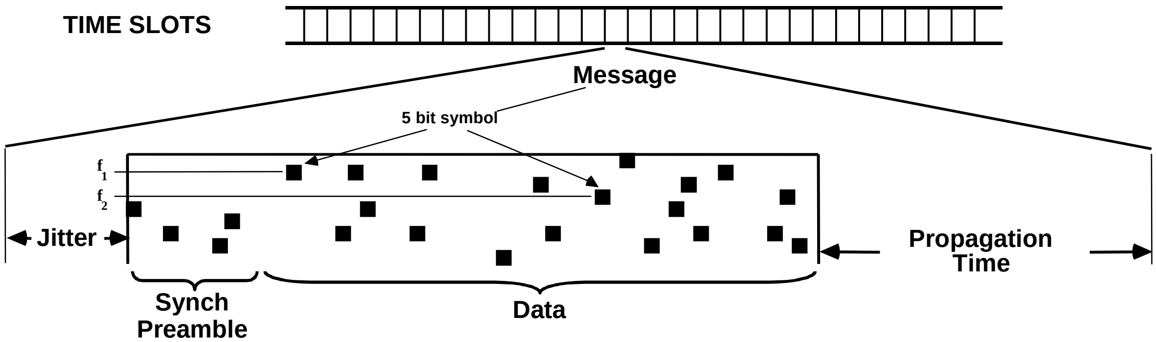
The exchanged messages are divided into 5 bit symbols, and each symbol is transmitted on a different pulse. In fact, for the standard time slot, each symbol is transmitted on two different pulses with two distinctly different carrier frequencies This increases the jam resistance of the transmission. While the jammer may take out one frequency, it is less likely to take out both. This is called a standard double-pulse time slot. The JTIDS Class 1 terminal can only use standard double-pulse time slots, but the JTIDS Class 2 and MIDS terminals support alternative time slot structures. The standard time slot including the synch preamble carries 258 symbols (i.e., 258 pulses).

The first alternative is called packed two double pulse[20]. A packed two double pulse time slot doubles the number of data symbols which can be transmitted. It does not double the number of synch symbols, so the total number of symbols (i.e., pulses) is expanded to 444, not 516[21]. To make room for the increased number of pulses, there is no jitter (i.e., the synch preamble starts at the beginning of the time slot) and there is only 300 nm of propagation time before the next slot occurs. Therefore, packed two double pulse transmissions are more susceptible to a smart partial-time jammer. Packing limits for transmitted data is selectable by network participation group (NPG). A receiving terminal automatically receives any transmitted packing. For example, terminal initialization data can be defined which will instruct the E-3 terminal to transmit PPLIs (NPG 6) with a packing limit of standard double-pulse and surveillance (NPG 7) with a packing limit of packed two double pulse. The PPLIs will exhibit resistance to a smart partial-time jammer and can be received at over 300 nm of range when the network is operated with the extended range mode. The packed two double pulse surveillance transmissions will be susceptible to the smart partial-time jammer and limited to a 300 nm reception range[22] even when the network is operated in the extended range mode.

[20] The packing alternatives are actually packing limits. If there is a queue of messages in the terminal awaiting transmission, then the terminal will use the packing limit. But, if there is not sufficient messages queued in the terminal to warrant the increased capacity, for example of packed two double pulse, then a lower packing limit such as standard double pulse, will be used. However, in practice, the flight processors tend to keep the queue in the terminal long enough to use the assigned packing limit, and so the assigned packing limit is normally the actual packing utilized.

[21] i.e., twice the 258 symbols in a standard slot

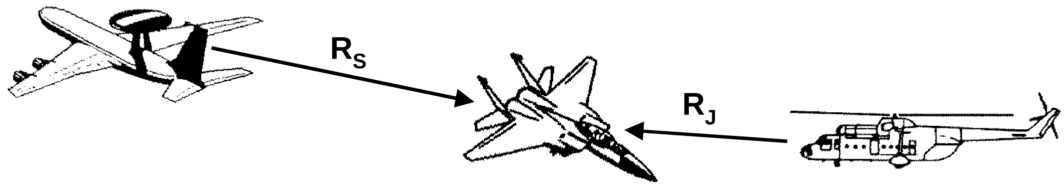
[22] Actually, the first half of the packed two double pulse data will be received at extended ranges. Only the last half will be lost. In the surveillance example, a packed two time slot can carry two to three air tracks and the first track in the slot will be received at extended ranges. So combat operators may see some of the data of an NPG assigned at packed two double pulse at extended ranges.



3.8-2 Modes of Operation – Message Packing

The second alternative is called packed two single pulse. This retains the same number of data pulses and the jitter and range mode options, but transmits each symbol with only a single pulse. This too doubles the number of symbols which can be transmitted, but it does it at the expense of jam resistance to the most likely forms of jammer. The third alternative is called packed four single pulse. It combines both the compromises of the packed two alternatives to quadruple the number of symbols which can be transmitted. Note that the number of symbols/pulses in a standard and packed two single pulse time slot is 258 and the number of symbols/pulses in a packed two double pulse and packed four single pulse time slot is 444. This will be important to understand when frequency management is discussed subsequently.

The jam margin of JTIDS/MIDS is classified, but the reduction in jam margin due to single pulse, both packed two and packed four, over double pulse is not. That's discussed next.

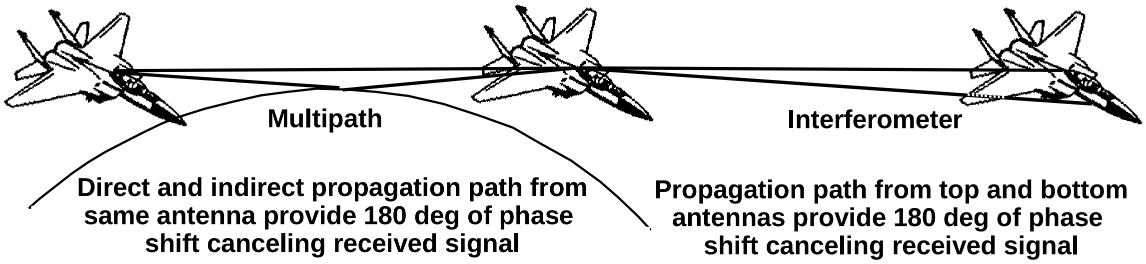


3.9 Modes of Operation – Single Pulse AJ Reduction

For the JTIDS Class 2 terminal, the antijam (AJ) margin against a full-band white noise jammer for single pulse is 2.2 dB less than that for double pulse. It is useful to look at the operational impact of this loss in AJ margin[23]. In the figure we have an F-15 approaching the forward edge of the battle area and facing a heliborne jammer. The F-15 wishes to receive situational awareness from an E-3 in the rear. Range to the jammer is R_J (nm) and the range to the E-3 (i.e., the signal source) is R_S (nm). A change in AJ will have the following impact on the relative ranges to the jammer and/or signal sources. If $R_S^{SP} = R_S^{DP}$ (i.e., we hold the range to the E-3 constant) then $R_J^{SP} = R_J^{DP} \times 10^{-[(AJ_{SP} - AJ_{DP})/20]}$ and if $R_J^{SP} = R_J^{DP}$ (i.e., we hold the range to the jammer constant) then $R_S^{SP} = R_S^{DP} \times 10^{[(AJ_{SP} - AJ_{DP})/20]}$ where $AJ_{SP} - AJ_{DP} = -2.2$ dB.

For an example, suppose we are using packed two double pulse and have an F-15 near the forward edge of the battle area who wishes to receive from an E-3 150 nm back ($R_S^{DP} = 150$ nm) and can tolerate a jammer of some power proceeding to within 75 nm of the F-15 ($R_J^{DP} = 75$ nm) before it experiences a 1% received message error rate (MER). Now suppose that we shift to packed four single pulse. This will reduce AJ by 2.2 dB. If the F-15 stays 150 nm away from the E-3 (i.e., $R_S^{SP} = R_S^{DP}$), the jammer need only proceed to within 97 nm of the F-15 to cause the MER to exceed 1% rather than the nominal 75 nm with packed two double pulse (i.e., $R_J^{SP} = 75 \times 10^{-[-2.2/20]} = 97$ nm). The jammer can jam the F-15 from further away and so its harder to kill the jammer.

[23] This was done previously to discuss losses in jam margin due to multinetting.

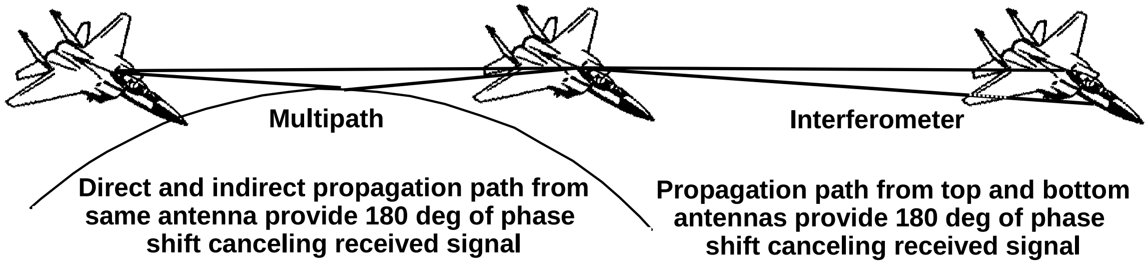


3.10 Modes of Operation – Multipath and Interferometer Effects

While the impact of single pulse on jam resistance is modest, its use also adversely impacts on the data link's resistance to multipath and interferometer effects. Both are depicted in the figure. Multipath is when the transmitted signal bounces off a reflective surface and impinges on the receiving antenna with a signal strength quite close to that of the direct signal. The phase shift between the direct signal and the reflected signal can just as likely as not be 180º, and if at or close to 180º the reflected signal will cancel out the direct signal and the pulse will not be received. With a double pulse structure, the frequency of the second pulse is different enough from that of the first that it has an independent 50/50 chance of not having an equivalent phase cancellation problem. So the second pulse significantly helps the reception probability. This help is lost with the single pulse structure. Even if the data is successfully exchanged, with single pulse the multipath can erode the jam resistance. This loss is significant enough and the likelihood of multipath over a reflective sea is high enough, that the Navy has chosen not to employ single pulse for their data exchanges, even to realize the improved capacity of packed four. The Air Force has used packed two single pulse over land with success for daily training, even over a reflective desert.

The E-3 and the F-15 both split the JTIDS signal and transmit half of the total power out of each of two antennas[24]. This can lead to losses in reception probability due to interferometer effects. This is depicted in the figure for F-15s. The F-15 to the right is shown transmitting from its top and bottom antenna. A receiving antenna within ±10º of the water line of the aircraft will receive both signals with about the same signal strength, but the geometry is such that it is just as likely as not that the two signals are out of phase as in phase, just like for multipath. This is because the wavelength of the signal is short (about 1 foot) compared with the distance between the two antennas. As with multipath, the double pulse structure significantly improves the reception probability in the face of interferometer effects. The E-3 transmits half the total power out of a horn antenna pointed out of the nose, and the other half out of a horn antenna out of the tail. So the area of equal signal strength is at ±90° to the fuselage (i.e., out of the wings).

[24] Rivet Joint does not, using only one antenna on the tail of the aircraft.



3.11 Modes of Operation – Changing Packing Limits

Operators/managers should be cognizant of the potential multipath and interferometer problems associated with single pulse, and its reduced jam resistance. Operators should report regarding apparent losses in reception to the network manager, particularly if operating where multipath is anticipated (e.g., over water) or if associated with interferometer effects (e.g., as the E-3 turns and sweeps its wing past a receiving platform).

Packing limits can be changed while in flight in the Rivet Joint and E-3[25]. However, changes should be coordinated upon by the network manager (including the wing/unit manager acting as network manager). Network operating constraints may preclude the change in packing limits. This will be discussed further in the Network Management I section.

In the E-3, the communication technician can make a change to packing limit via the Control Monitor Set (CMS) while the E-3 is transmitting. Receiving units will automatically adjust and receive transmissions with the new packing. For example, if the E-3 is assigned packed four single pulse for surveillance to acquire maximum capacity and the network manager (via the operators) finds that data exchange performance is suffering, the packing limit can be changed to packed two double pulse. Of course, in this example, the surveillance transmit capacity will be cut in half and the surveillance operators may have to make an adjustment regarding the number of tracks being reported (or accept a reduced update rate).

The change to packing in the Rivet Joint cannot be done while the aircraft is transmitting. The data link operator must change the packing in the stored initialization data set, then perform a standby-on[26], then load the terminal with the changed data set, then reenter the network.

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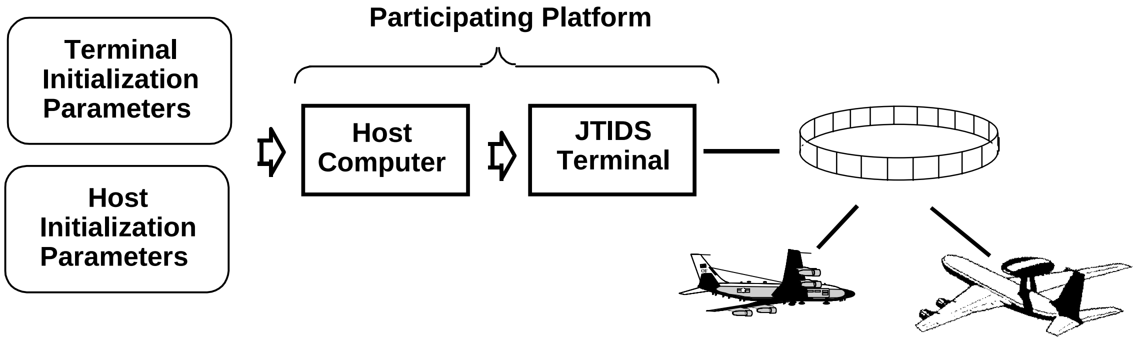
[25] and even in the F-15 if it is provided optional initialization data sets. The F-15 pilot can carry two initialization data sets on his data transfer module (DTM) and load either into the terminal.
[26] Turn the terminal to standby, then back to on.

4.0 Network Management I

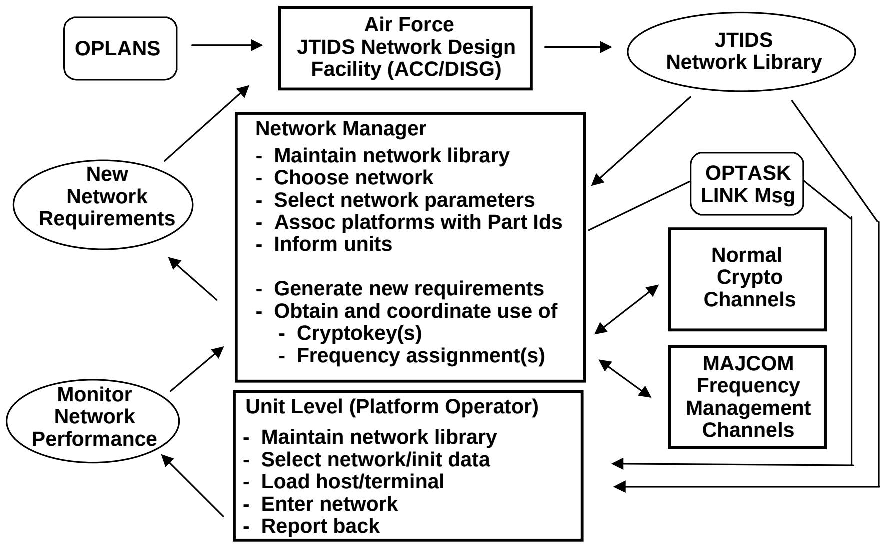


4.1 Network Management I – Management Process

To operate a Link 16 network it is first necessary to determine the network requirements. This is basically who has to talk to who about what and how much. Network requirements specification will be discussed in some detail subsequently, in this section. Once requirements are specified the time slots can be allocated to each network participant and operating modes selected (e.g., range mode). This is termed network design. Since the behavior of the terminals and host processors in a Link 16 network is governed by initialization parameters, the time slot allocation and mode selections of the network design produce initialization data sets which must then be distributed to the network participants. Each participant then selects a few host specific parameters, loads the initialization data sets into his/her[1] host processor and Link 16 terminal, and enters the network (i.e., becomes time synchronized with the other network participants so they can exchange information). He then monitors his operation in the network and reports back to the network manager.

This section will begin the discussion of the network management process for operating Link 16 networks. It will present a set of duties for the wing and unit managers, and describe the OPTASK LINK message required to coordinate on Link 16 network operations. However, it will discuss the process only in so far as the technical information given herein or in the previous sections provides a suitable understanding to the reader. Additional technical topics will then be discussed in subsequent sections, and the network process elaborated upon based on the additional information thus provided. At the end of the technical topics, another section will be provided, Network Management II, which will summarize all of the management duties and OPTASK LINK elements accumulated throughout the document to that point.

[1] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.



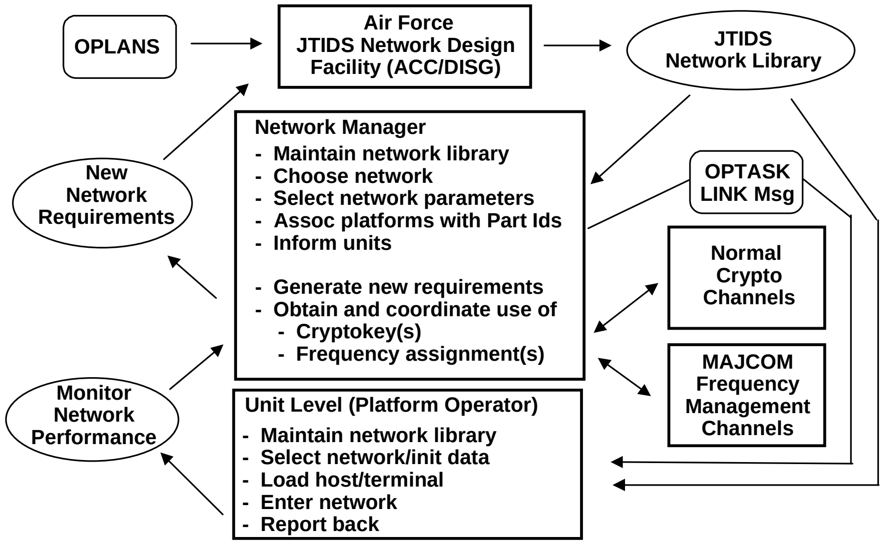
4.2-1 Network Management I – Management Roles

The basic roles involved with network management are shown in the figure. We begin as if only the Air Force is operating. Joint and allied operations will follow. The intended operation is that the network design facility will refer to the standing OPLANs and, for each OPLAN, design one or more Link 16 network which is suitable for use when the operation is put into effect. Normally, the Link 16 network will be part of a larger multi TADIL network. The networks will be designed in terms of generic participants (e.g., E3(1), RJ(1), CRE(1), CRE(2), JSTARS(1), F15(1.1.1[2]), F15(1.1.2), ...). Each network is named, and network descriptions and the initialization data sets for the generic network participant identifiers are then sent to all potential network managers and all potential network participants. There they are held in a local network library ready for use. They are also cited in the associated OPLAN. This phase of network management is termed the design phase.

Once designed a network can be used for any operation. In fact, it may be that the same network is cited for several OPLANs. The network names themselves are generic, and do not convey information regarding the theater of their intended use. Therefore, while the OPLANs are classified, the generic Link 16 networks are not.

Once in the library, a network can be chosen for use. The network manager in theater will be the joint interface control officer (JICO). He will refer to the OPLANs and the Link 16 network library, and will select a network for use. He will associate each actual participant by unit and voice call sign with a generic network participant identifier (e.g., 964 AWACS, call sign Magic, is E3(1); 726 ACS, call sign Blue Boy, is CRE(1); ....). He must select a few initialization parameters unique to theater operation and must designate certain participants to play special roles in the network, also unique to the operation. Then, all of

[2] F-15s use a noded identifier where the last node represents a particular F-15, the second node might represent a particular flight, and the first node might represent a particular capability (e.g., 1 for 16 kbps voice and 2 for 2.4 kbps voice).



4.2-2 Network Management I – Management Roles

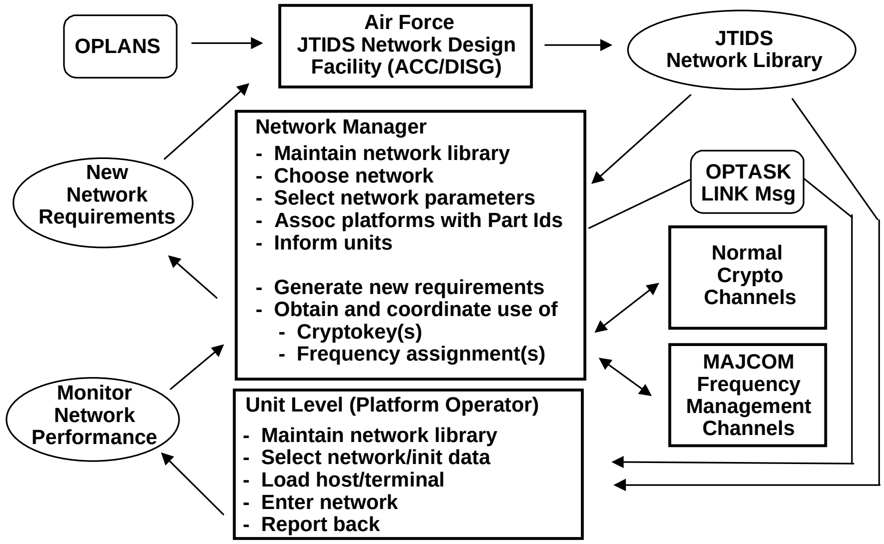
this information must be distributed to the network participants. This is done using the OPTASK LINK message. This phase of network management is termed the planning phase.

At the unit, the platform communication operator selects the appropriate initialization data set from his local library. The Air Force terms the initialization data set the network design load (NDL). His NDL is uniquely determined by network name and participant identifier. The communication operator adds (actually modifies[3]) the parameters received from the OPTASK LINK and adds (actually modifies) a small set of locally determined parameters. He is then ready to begin network operations. This phase of network management is termed the initiation phase.

The communication operator loads his platform host processor and his Link 16 terminal and proceeds to enter the network (i.e., become time synchronized). If he has trouble entering the network he reports back to the network manager. If he succeeds in entering the network he monitors network operations from his perspective and that of his platform's operators, and reports this back to the network manager. This can be done by voice radio in real time, and/or at debrief at the end of the mission.

This is all well and good for the first days of an operation, assuming the OPLAN was close. But network requirements are expected to change quickly. In response to this the network manager will request new networks and modifications to current networks of the design facility. The design facility will create the new networks and distribute their descriptions and NDLs to the appropriate units/platforms. The distribution can actually take longer than the network design process itself. The Air Force has developed the capability to

[3] The NDL actually contains all parameters which have to be entered, but those which will be determined in theater are given default values, normally zero. So their entry at the platform are really modifications to the defaults.

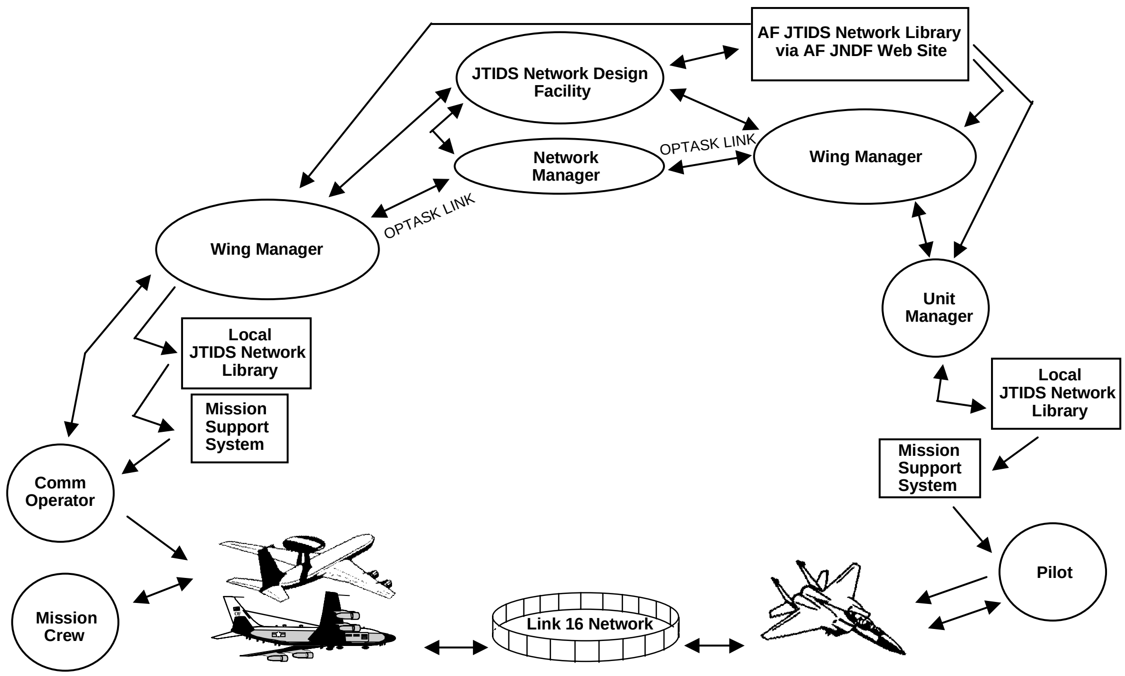


4.2-3 Network Management I – Management Roles

distribute their networks and NDLs electronically, recently via the Internet. Their goal is to create and distribute a new network within 24 hours of receiving a request.

In practice, a JTIDS network library has not been created with reference to the OPLANs. As each new network has been required it has been designed and, if suitable for reuse, added to a JTIDS Network Library (JNL). So there is a JNL, but thus far it has been created ad hoc, rather than with reference to the OPLANs.

There are two additional duties for the network manager. Link 16 is a secure radio system, and so utilizes cryptokey. The cryptokey to be used by all of the participants in a network must be coordinated and properly loaded into the terminals. This is the job of the network manager. In addition, Link 16 operates in the same radio frequency band as radionavigation aids, and there are requirements imposed on the operation of the data link system by the Federal Aviation Administration (FAA). Meeting these responsibilities is the job of the network manager. However, this section will not discuss either cryptokey or frequency management in any detail. They will be discussed in separate sections subsequently.



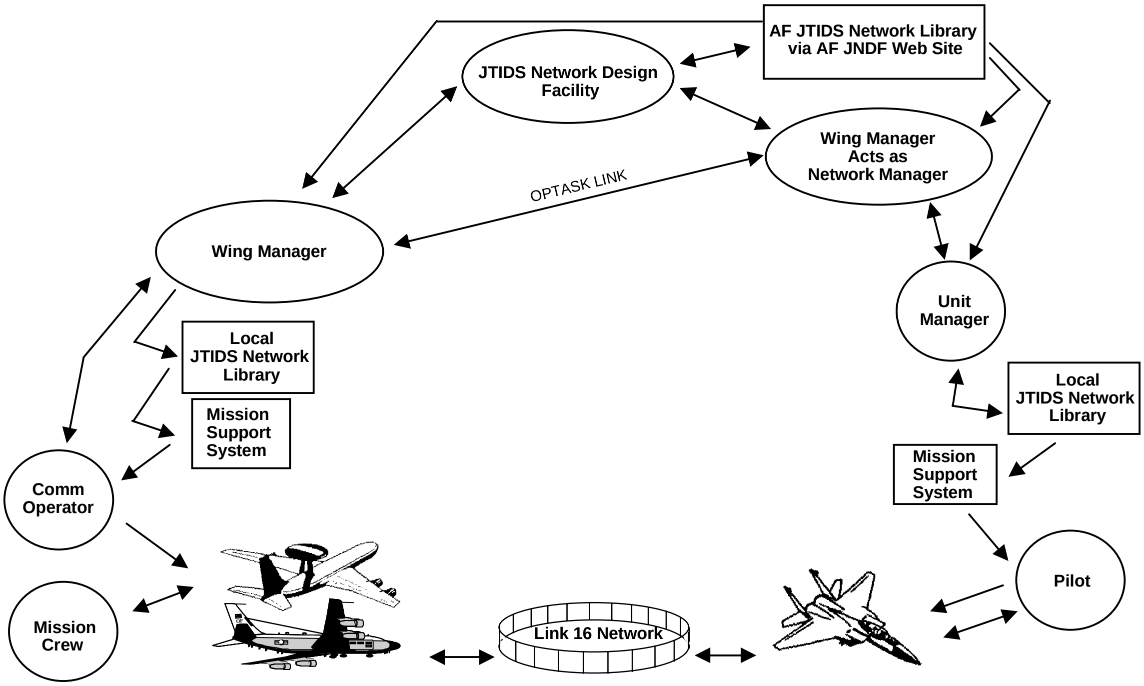
4.3 Network Management I – Deployed Responsibilities

The Air Force has defined points of contact (POCs) at wing and unit level to act as Link 16 experts and interfaces between wing/unit and other elements of the Link 16 operational infrastructure. These are not additional personnel, but current personnel with a specific assigned additional responsibility. This is done for other platform systems and is critical for Link 16. At some bases such as Tinker AFB and the 522 ACW, there is only a wing manager. At others such as Mt Home AFB, units such as the 390 FS and 726 ACS will have unit managers and there will be an overall coordinating wing manager as well. At bases which only have a single unit equipped with Link 16, there may only be a unit manager[4]. He will act as wing manager.

<u>The wing/unit manager will act as the interface between the wing/unit and the AF JNDF</u>. Networks including their description and associated NDLs can be mailed, by post or electronically. However, with the rather large fielding being planned, this manner of "pushing" out the networks is labor intensive. Therefore, the AF JNDF has established a web site[5] from which the networks can be "pulled" by the wing/unit managers. <u>The web site should be visited by the wing/unit managers at least once per week to ensure they have the latest network information</u>. <u>The new and revised networks should be pulled from the web site and stored locally</u>. <u>They should be carefully logged including their date</u>. Wings/units should not rely on the Internet or the web site for their short term Link 16 operations.

<u>When his platforms are deploying to work in a Link 16 network, the wing/unit manager will act as the interface between his individual platforms and the network manager.</u> <u>This will require an understanding of the OPTASK LINK message</u>.

[4] This was the case at Mt Home AFB when only the 390 FS was equipped with Link 16. With the equipping of the 726 ACS and two B-1 bombers, the 366 WG has designated an overall wing manager.
[5] http://totn.do.langley.af.mil. For a password to download init data e-mail af.jtids@langley.af.mil.

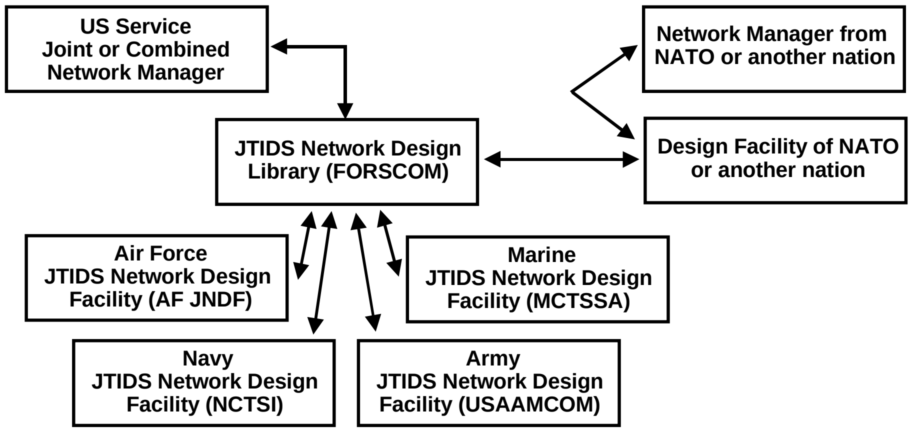


4.4 Network Management I – Responsibilities During Daily Training

For daily training, the wing/unit manager may act as the network manager for locally operated networks. He will determine the requirements for those networks and request them of the AF JNDF. He will coordinate the network operation using the OPTASK LINK message[6].

Throughout the document we will build the duties of the wing/unit manager. As we do, we will separate the functions required if the wing/unit platforms are deploying to operate in a network managed by someone other than the wing itself, and those duties required if and when a wing/unit manager is acting as a network manager for training exercises. These latter duties are much more demanding than the former. Wing/unit managers for platform types which will normally deploy to Link 16 networks, even for daily training, will have a much easier time of it. However, there must be a network manager for every network, even if it is simply the flight leader for a simple four-ship flight of fighters operating autonomously. Ad hoc Link 16 networks are not encouraged. They will tend to breed procedures which are not suitable for larger wartime network operation. In addition, frequency management responsibilities discussed subsequently will motivate a network manager for each network[7].

[6] Informal procedures can be used, but this document will encourage the use of the OPTASK LINK message.
[7] Remember, a network is a collection of participants all in time synchronization and able to exchange information.



4.5 Network Management I – Joint and Allied Operations

While requests for Air Force-only networks will go to the Air Force JTIDS Network Design Facility (AF JNDF), requests for joint or allied networks should go to the JTIDS Network Design Library (JNDL) of FORSCOM at Ft McPherson, GA. The JNDL has a web site[8]. A password is required, but the web site supports a request for one. The Air Force network manager can also seek help from the AF JNDF in making the request. It is advisable for an Air Force network manager to coordinate a joint or allied network request with the AF JNDF, even if requesting directly to the JNDL.

For joint networks, the JNDL will examine the joint JTIDS network library (JNL) for a network which meets the needs of the requestor. If there is no existing network, the JNDL will assign one of the service design facilities as lead for the network design. All four services have design facilities as depicted in the figure. The lead design facility will work directly with the requestor, although the requestor can request assistance from their design facility if they are not the lead designer. The lead design facility will coordinate their design with the JNDL and the service design facilities of the services involved in the network. When they have completed the design it will be deemed suitable by the requestor, the JNDL and all of the associated service design facilities. This has been working out quite nicely for some time now. The completed network will be placed in the joint JNL and be made available to all service design facilities. Each service design facility will prepare the network descriptions and NDLs for their service platforms and distribute them, just as if the network was an Air Force-only network. So individual units will always receive their networks from their service design facility (i.e., for the Air Force, the AF JNDF at Langley AFB).

For allied networks, whether requested by a US service, the service of another nation or NATO, the JNDL will negotiate a lead design facility with the design facilities of the other nations and/or NATO. Once negotiated, the process works just as if it was a US-only network. The lead design facility works directly with the requestor, although the requestor can request assistance from their design facility if they are not the lead designer. The completed network will be distributed by the service design facilities. So, for example, F-15Cs based at Lakenheath, UK will receive their combined US/UK networks from the AF JNDF at Langley AFB, not from the UK. This is important to understand.

[8] http://jndl.forscom.army.mil

```
CONNECTIVITY MATRIX                                                                   EXAMPLE

                    SLOT GROUP|1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18
                          TSEC|1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    2
                          MSEC|
              MESSAGE CATEGORY|P    P    T    T    V    3    6    TY   6    7    7    TY   8    TY   9    9    19   20
                   ACCESS MODE|     7                   4              8                             16   8    14   14
                 PACKING LIMIT|                              2         2    2    2         2         2    0    2    2
          PER UNIT SLOTS/FRAME|1                             1              32   32        4
             TOTAL SLOTS/FRAME|16   96   128  64   128  16   16   16   96   64   64   64   16   16   16   64   160  96
----------------------NET-TSEC+---------------------------------------------------------------------------------------
    E3I(1)          |    |    |T/R  R    T    R    T
    E3(1)           |0   |1   |                    T    T    T/R  Y    R    T/R  R    Y    T/R  Y    T    R
    CRC(1)/2        |0   |1   |                    T    T    T/R  R    R    R    T/R  R    T/R  R    T    R
    RJ(1)           |0   |1   |T/R       R    T    T    T    T/R  R    R    T/R  R    R    R    R
    F15(1.1.1)      |0   |1   |R    T    R         T    T    R         T    R    R         R         R    T    T    T
```

4.6-1 Network Management I – Connectivity Matrix

The design facility will design a requested network using a network design computer aid. The network requirements are entered into the computer aid using a connectivity matrix. These requirements are drawn from the network manager's request. To better understand the information which should be provided in the network request, we will describe the connectivity matrix. The matrix is a part of the network description which is provided to the wing/unit manager, and it clearly indicates the capabilities of the network. This is another good reason for the wing/unit manager to understand its format.

The matrix[9] will be described using an example. Supporting the description and to help the wing/unit manager to interpret matrices, a "cheat sheet" covering the important elements of the matrix is given in the following subsection. The example is the same one discussed in the architecture section. Present are an E-3, a Rivet Joint, two CREs and some F-15Cs. The F-15s will use contention access and with the pools used, up to 20 F-15s will be able to participate in the network before the performance of the most distant F-15 becomes less than satisfactory. In the example we do not know if the E-3 will be a Class 1 terminal equipped block 20/25 E-3 or a Class 2 terminal equipped block 30/35 E-3. So the network will be required to operate with either. However, it will not be designed to operate with both at the same time. Such a mixed IJMS and TADIL J operation is difficult to manage, although just why will not be discussed in this document[10].

The first thing that a network manager must specify in a network request is who should be in the network. They may not all be there at the same time. That's all right. Parts of networks can be used just fine (e.g., an E-3 could use the example network with F-15s alone without the Rivet Joint and the CREs). The generic participant identifiers are E3I(1) for the block 20/25 E-3 (i.e., the I denotes Class 1 and the (1) denotes the first if there are more than one), E3(1) for the block 30/35 E-3 (i.e., lack of an I denotes Class 2 terminal equipped), and CRC(1)/2 represents the two CREs, both with Class 2 terminals. When the NDLs are prepared, the individual CRE participant identifiers will be CRC(1.1) and CRC(1.2). RJ(1) denotes the Rivet Joint and F15(1.1.1) denotes all of the F-15s. Remember, with contention access, all of the F-15s use the same NDL, so we only need to have one F-15 in the network design. Each of the network participants is represented by a row of the connectivity matrix.

---

[9] The format described is that of the engineering model computer aid (WinATI). The joint service Network Design Aid (NDA) format differs slightly.

[10] Since soon after its release all E-3s are expected to be upgraded to block 30/35 status.

```
 CONNECTIVITY MATRIX                                                                       EXAMPLE

                SLOT GROUP|1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18
                      TSEC|1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2
                      MSEC|
          MESSAGE CATEGORY|P   P   T   T   V   3   6   TY  6   7   7   TY  8   TY  9   9   19  20
               ACCESS MODE|    7               4           8                           16  8   14  14
             PACKING LIMIT|                        2       2   2   2       2       2   0   2   2
      PER UNIT SLOTS/FRAME|1                       1           32  32      4
         TOTAL SLOTS/FRAME|16  96  128 64  128 16  16  16  96  64  64  64  16  16  16  64  160 96
------------------NET-TSEC+---------------------------------------------------------------------------
    E3I(1)       |   |    |T/R R   T   R   T
    E3(1)        |0  |1   |                T   T   T/R Y   R   T/R R   Y   T/R Y   T   R
    CRC(1)/2     |0  |1   |                T   T   T/R R   R   R   T/R R   T/R R   T   R
    RJ(1)        |0  |1   |T/R     R   T   T   T   T/R R   R   T/R R   R   R   R
    F15(1.1.1)   |0  |1   |R   T   R       T   T   R       T   R   R       R       R   T   T   T
```

4.6-2 Network Management I – Connectivity Matrix

Once the participants are established, but before the matrix can be expanded, two issues must be resolved. First, the range mode must be selected. Range mode is a network-wide parameter (i.e., all network participants must use the same range mode). The extended range mode[11] is of some value for extending the range of direct exchanges between airborne platforms[12], although it is unlikely that the whole 500 nm range can be utilized due to line of sight limitations. There are synchronization and navigation limitations for platforms operating more than 300 nm from the main body of a Link 16 network when the extended range mode is used. These limitations are discussed subsequently and must be accommodated when extended range is used. Because of these limitations, and the apparent utility of the normal range mode to date, networks are nominally designed with the normal range mode unless extended range is expressly requested by the network manager.

The second issue involves frequency management. This topic will be discussed in detail in a subsequent section, but it will be summarized here sufficient for this discussion. Link 16 operates in the same radio frequency band as radionavigation aids. Therefore, for operations in the US and her possessions (US&P), the Federal Aviation Administration (FAA), who controls the use of the band, imposes significant requirements and constraints on its use. Similarly, the civil aviation authorities of other nations control this band in their airspace and impose similar requirements and constraints. Of concern here is that every network must operate under a frequency assignment, in the US&P granted by the NTIA[13]. The network must be designed in accordance with the requirements and constraints as described in the frequency assignment under which it will be operated. The network manager is responsible for ensuring there is an appropriate frequency assignment, understanding its requirements and constraints, and operating the network in accordance with those requirements and constraints. This extends to the wing/unit manager when managing networks for daily training. Therefore, the network manager must make the frequency assignment under which a network will operate known to the network designers, or at least the requirements and constraints which will impact on the network design. The example we


```
 CONNECTIVITY MATRIX                                                                       EXAMPLE

                SLOT GROUP|1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18
                      TSEC|1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2
                      MSEC|
          MESSAGE CATEGORY|P   P   T   T   V   3   6   TY  6   7   7   TY  8   TY  9   9   19  20
               ACCESS MODE|    7               4           8                           16  8   14  14
             PACKING LIMIT|                        2       2   2   2       2       2   0   2   2
      PER UNIT SLOTS/FRAME|1                       1           32  32      4
         TOTAL SLOTS/FRAME|16  96  128 64  128 16  16  16  96  64  64  64  16  16  16  64  160 96
------------------NET-TSEC+---------------------------------------------------------------------------
    E3I(1)       |   |    |T/R R   T   R   T
    E3(1)        |0  |1   |                T   T   T/R Y   R   T/R R   Y   T/R Y   T   R
    CRC(1)/2     |0  |1   |                T   T   T/R R   R   R   T/R R   T/R R   T   R
    RJ(1)        |0  |1   |T/R     R   T   T   T   T/R R   R   T/R R   R   R   R
    F15(1.1.1)   |0  |1   |R   T   R       T   T   R       T   R   R       R       R   T   T   T
```


---

[11] Altering jitter to extend range from the normal 300 nm to 500 nm.
[12] Line of sight limitations makes extended range of limited use for exchanges with surface platforms.
[13] National Telecommunication and Information Administration, but with FAA involvement

will be using here is assumed to be supported by a frequency assignment which permits use of the contention access transmission mode by the F-15s as well as 2.4 kbps voice. This has been the case for F-15s operating in their miltary operating areas (MOAs) at Mt Home and Nellis AFBs since the start of Link 16 operations in the F-15s at those bases.

The columns of the connectivity matrix represent communication transactions (i.e., a participant transmits in a given NPG to other participants). When all of the required transactions are specified and the network is designed, there may be time slots left over, unassigned to any participant. During these time slots the terminals will receive, on a default net with a default transmission security (TSEC) cryptokey[14]. A default net and TSEC must be assigned to each participant. The actual cryptokey by title will not be assigned. A label will be assigned which represents the cryptokey. The label is called a cryptovariable logical label (CVLL) and is simply a numeric value from 1 to 127. As cryptokeys are identified for use in the network we assign CVLLs, not actual cryptokey titles. The actual cryptokeys are associated with the labels when the network is put into operation. This is discussed in detail subsequently in the cryptokey section. The CVLLs are assigned by simply starting with 1 and proceeding up the numeric sequence. The default net (NET) and default TSEC are specified for each participant as the last two items on each row before the communication transactions start. The Class 1 terminal does not require default TSEC since it uses only one cryptokey, nor a default net (NET) since the default net is the same net on which the terminal transmits its IJMS messages. Like much of the material that is specified in the matrix, the default net and encryption requirements are established by policy and/or network design guidelines. The policies and guidelines are known to the Air Force JTIDS Network Design Facility (AF JNDF) and so need not concern the network manager requesting the network.

The communication transactions are called slot groups. They are labeled in sequence starting with 1. In the example, the first few slot groups concern IJMS transmissions which are required when the block 20/25 E-3 is the E-3 present. Before describing them we should point out that the CREs do not exchange IJMS. Their Class 2 terminal is a bilingual terminal, but it is a pass through terminal like that of the E-3, not a translating terminal. It was intended that the CRE/CRC processor would exchange both IJMS and TADIL J, just

[14] The TSEC cryptokey establishes the frequency hopping pattern, jitter, etc. For default receipt, the messages are also assumed to be encrypted with the TSEC cryptokey.

```
 CONNECTIVITY MATRIX                                                                      EXAMPLE

                SLOT GROUP|1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18
                      TSEC|1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2
                      MSEC|
          MESSAGE CATEGORY|P   P   T   T   V   3   6   TY  6   7   7   TY  8   TY  9   9   19  20
               ACCESS MODE|    7               4           8                       16  8   14  14
             PACKING LIMIT|                        2       2   2   2       2       2   0   2   2
      PER UNIT SLOTS/FRAME|1                       1           32  32      4
         TOTAL SLOTS/FRAME|16  96  128 64  128 16  16  16  96  64  64  64  16  16  16  64  160 96
------------------NET-TSEC+--------------------------------------------------------------------------
    E3I(1)       |   |    |T/R R   T   R   T
    E3(1)        |0  |1   |                T   T   T/R Y   R   T/R R   Y   T/R Y   T   R
    CRC(1)/2     |0  |1   |                T   T   T/R R   R   R   T/R R   T/R R   T   R
    RJ(1)        |0  |1   |T/R     R   T   T   T   T/R R   R   T/R R   R   R   R
    F15(1.1.1)   |0  |1   |R   T   R       T   T   R       T   R   R       R       R   T   T   T
```

4.6-4 Network Management I – Connectivity Matrix

like the block 30/35 E-3. However, the IJMS part of the exchange was not funded. Since the terminal was not a translating terminal, this left the CRE/CRC out of the IJMS picture for information exchange[15]. If a block 20/25 E-3 is present and the CREs are operating TADIL J, there is no way for the E-3 and the CREs to coordinate their surveillance transmissions[16], and the F-15s and Rivet Joint will see a confused air picture[17]. Therefore, when the E-3 present is a block 20/25 E-3, the network design will assume that the CREs will not use JTIDS, but employ TADIL A in a multi TADIL network.

In slot group 1 the E-3 and the Rivet Joint exchange IJMS position reports (P-messages) using the main TSEC which has been given a CVLL=1. The messages will be encrypted using the TSEC cryptokey since no separate message security key (MSEC) is specified. This is normal. Each of the two transmitting participants will be assigned 1 slot per 12 second frame (1 s/f) as given in the per unit row. The 16 s/f as given in the total row are reserved for these P-message transmissions although only 2 s/f will be used (i.e., 1 s/f for each of the two platforms). Each participant will be assigned a unique 1 s/f transmit time slot assignment drawn from the 16 s/f block, and when not transmitting will receive the other 15 s/f from the 16 s/f block[18]. This is denoted by the T/R for each of the two transmitting participants in the column for their respective rows. The F-15s receive the entire 16 s/f block. Note that if the network has to be modified to add participants, there is room for 14 more P-message transmissions in this slot group. The block 30/35 does not participate since if we are doing IJMS, it is not present, and the CREs do not participate since they don't do IJMS at all. The P-message transmit time slot assignments are made to the Class 2 terminals via NPG 30. All IJMS receives are assigned via NPG 31. Packing limit is not specified since all IJMS exchanges use standard double pulse. Access mode is not specified since no entry means dedicated access.

Slot group 2 represents the transmission of P-messages by the F-15s using contention access. The pool size is given in the total row as 96 s/f. The access interval is 3 seconds and is specified with a code (i.e., a code of 7 means 3 seconds). The code is given in the cheat

[15] However, it will transmit an IJMS P-message if it is given a NPG 30 transmit assignment.
[16] Since the block 20/25 E-3 exchanges only IJMS, the CREs exchange only TADIL J and the two message sets are incompatible.
[17] Duplicate air tracks
[18] It actually receives a 16 s/f receive assignment which includes the 1 s/f transmit assignment, but the terminal is perfectly happy with the overlapping transmit over receive assignments.

```
 CONNECTIVITY MATRIX                                                                EXAMPLE

                SLOT GROUP|1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18
                      TSEC|1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2
                      MSEC|
          MESSAGE CATEGORY|P   P   T   T   V   3   6   TY  6   7   7   TY  8   TY  9   9   19  20
               ACCESS MODE|    7                   4           8                       16  8   14  14
             PACKING LIMIT|                            2       2   2   2       2       2   0   2   2
      PER UNIT SLOTS/FRAME|1                           1           32  32      4
         TOTAL SLOTS/FRAME|16  96  128 64  128 16  16  16  96  64  64  64  16  16  16  64  160 96
------------------NET-TSEC+-------------------------------------------------------------------------
    E3I(1)       |   |    |T/R R   T   R   T
    E3(1)        |0  |1   |                T   T   T/R Y   R   T/R R   Y   T/R Y   T   R
    CRC(1)/2     |0  |1   |                T   T   T/R R   R   R   T/R R   T/R R   T   R
    RJ(1)        |0  |1   |T/R     R   T   T   T   T/R R   R   T/R R   R   R   R
    F15(1.1.1)   |0  |1   |R   T   R       T   T   R       T   R   R       R       R   T   T   T
```

4.6-5 Network Management I – Connectivity Matrix

sheet. The Rivet Joint need not receive the P-messages from the F-15s. The F-15s will also transmit PPLIs which the Rivet Joint will receive.

In slot group 3 the E-3 transmits it surveillance and engagement status information. We've assigned 128 s/f. Using the 4/3 rule of thumb for IJMS this will support the reporting of 96 air tracks at the nominal 10 second reporting interval, plus other supporting messages. This is the next point at which some input is required from the network manager. He must specify the E-3 air track reporting capability demanded by the network (e.g., in this case he would have specified the 96 air tracks). The Rivet Joint and F-15s receive.

In slot group 4 the Rivet Joint transmits its surveillance data in IJMS. Only the E-3 receives. The Rivet Joint will simulcast its surveillance via IJMS (this slot group) and TADIL J (slot group 10) and the F-15s will receive the TADIL J. Its more complete information. The specification of the Rivet Joint IJMS transmit requirements is based on its TADIL J requirements, and for Rivet Joint this is a bit different than simply specifying air track reporting since it transmits a good deal more than air tracks in the surveillance NPG. An analysis[19] has been performed to determine all of the messages which the Rivet Joint would likely generate for two scenarios, a low intensity conflict which might also cover daily training and a high intensity conflict like Desert Storm. Time slot requirements were then determined in terms of those messages, for both surveillance (NPG 7) and electronic warfare (EW-NPG 10). When specifying surveillance and EW requirements for Rivet Joint, the network manager should size the requirement with respect to the two scenarios (e.g., half way between the two). The AF JNDF can then convert these to TADIL J time slot requirements. The IJMS requirements are then based on the requirements for NPG 7. The two Rivet Joint scenarios are as follows:

- Low Intensity Conflict[20] - 35 to 40 air tracks in the Rivet Joint coverage area with Rivet Joint actively amplifying approximately 70% of those tracks, supplementing coverage with its own air tracks, transmitting ground threats, etc.
- High Intensity Conflict[21] – Approximately 125 air tracks in the Rivet Joint coverage area with Rivet Joint actively amplifying approximately 60% of those tracks, supplementing coverage with its own air tracks, transmitting ground threats, etc.

[19] Reference MITRE Technical Report MTR 99B0000016 dated March 1999.
[20] Requires 10 s/f at packed two (5 s/f at packed four) for NPG 7 and NPG 10
[21] Requires 20 s/f at packed two (10 s/f at packed four) for NPG 7 and NPG 10

```
  CONNECTIVITY MATRIX                                                               EXAMPLE

                SLOT GROUP|1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18
                      TSEC|1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    2
                      MSEC|
          MESSAGE CATEGORY|P    P    T    T    V    3    6    TY   6    7    7    TY   8    TY   9    9    19   20
               ACCESS MODE|     7                   4              8                                  16   8    14   14
             PACKING LIMIT|                              2         2    2    2         2         2    0    2    2
      PER UNIT SLOTS/FRAME|1                             1              32   32        4
         TOTAL SLOTS/FRAME|16   96   128  64   128  16   16   16   96   64   64   64   16   16   16   64   160  96
-----------------NET-TSEC+-------------------------------------------------------------------------------------------
    E3I(1)       |    |    |T/R  R    T    R    T
    E3(1)        |0   |1   |                    T    T    T/R  Y    R    T/R  R    Y    T/R  Y    T    R
    CRC(1)/2     |0   |1   |                    T    T    T/R  R    R    R    T/R  R    T/R  R    T    R
    RJ(1)        |0   |1   |T/R       R    T    T    T    T/R  R    R    T/R  R    R    R    R
    F15(1.1.1)   |0   |1   |R    T    R         T    T    R         T    R    R         R         R    T    T    T
```

4.6-6 Network Management I – Connectivity Matrix

In slot group 5 we have coded 2.4 kbps voice shared among all participants. This is available to both E-3s, and suitable for fighter use being coded. For the Class 2 terminal equipped platforms the voice is voice A (NPG 12). This is the only voice that is contained in
the network. However, the F-15s could request voice B for interfighter use, or for private exchanges with Rivet Joint. This illustrates another requirement which the network manager must specify. Voice and its use is entirely optional, at least when permitted by the frequency assignment under which the network will be operated.

This completes all of the transactions that would involved the block 20/25 E-3. Slot group 6 starts the TADIL J portion of the network. If the block 30/35 E-3 is present the first four slot groups are largely irrelevant. Slot group 6 is for round trip timing (RTT) messages which are used by the terminal for synch. They are assigned with contention access, a 16 s/f pool with an access interval of 8 seconds. RTTs are described in the synch section.

In slot group 7 the block 30/35 E-3, Rivet Joint and two CREs all exchange PPLIs with a 12 second interval (i.e. 1 s/f each). This uses four of the 16 s/f reserved for the transaction. Except for RTTs, packing limit must be specified for TADIL J transactions. It is done with a code, and 2 means packed two single pulse. The code is given in the cheat sheet. The E-3 receives the PPLIs and then relays them in slot group 8. This is denoted by TY for message category, and Y for the matrix element for the relayer. With this relay the CREs will see each other's PPLIs. The F-15s do not receive the relay (i.e., no R in slot group 8). They don't process CRE PPLIs for data. The direct receipt will support navigation (to be discussed in detail subsequently). The F-15s can be assigned to do something else (e.g., fighter-to-fighter NPG 19) on a different net while the relay is taking place. In slot group 9 the F-15s exchange their PPLIs using contention access, and the E-3, CREs and Rivet Joint receive. The pool is 96 s/f and the access interval is 2 seconds. Packed two single pulse is used. The PPLIs are not relayed. This means that low flying F-15s will not see one another if they are not within line of sight. It also means that the CREs may not see low flying F-15s. This illustrates another requirement which the network manager must provide the designer. The designer requires the disposition of network participants and the associated relay requirements[22]. In this example it might be critical to have the F-15 PPLIs relayed to support low fliers. This takes additional capacity. It might force a tradeoff among other

[22] Or, at least the relay requirements.

```
 CONNECTIVITY MATRIX                                                                      EXAMPLE

               SLOT GROUP|1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16  17  18
                     TSEC|1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2
                     MSEC|
         MESSAGE CATEGORY|P   P   T   T   V   3   6   TY  6   7   7   TY  8   TY  9   9   19  20
              ACCESS MODE|    7               4           8                       16  8   14  14
            PACKING LIMIT|                        2       2   2   2       2       2   0   2   2
     PER UNIT SLOTS/FRAME|1                       1           32  32      4
        TOTAL SLOTS/FRAME|16  96  128 64  128 16  16  16  96  64  64  64  16  16  16  64  160 96
-----------------NET-TSEC+-------------------------------------------------------------------------
   E3I(1)       |   |    |T/R R   T   R   T
   E3(1)        |0  |1   |                T   T   T/R Y   R   T/R R   Y   T/R Y   T   R
   CRC(1)/2     |0  |1   |                T   T   T/R R   R   R   T/R R   T/R R   T   R
   RJ(1)        |0  |1   |T/R     R   T   T   T   T/R R   R   T/R R   R   R   R
   F15(1.1.1)   |0  |1   |R   T   R       T   T   R       T   R   R       R       R   T   T   T
```

4.6-7 Network Management I – Connectivity Matrix

network requirements. The Rivet Joint might be a better relay. It may be that both the E-3 and Rivet Joint should be relays. This takes more capacity, dictating further compromises.

Slot group 10 represents the transmission of surveillance by the block 30/35 E-3 and Rivet Joint. The method for the network manager to specify surveillance reporting requirements for the Rivet Joint has already been discussed. For the block 30/35 E-3, an analysis like than performed for the Rivet Joint has not been done. Therefore, the design facility will use a simple rule of thumb[23] based on the desired air track reporting requirement[24]. The network manager should specify the air track reporting requirement just as for the block 20/25 E-3. In this example we have assigned 32 s/f to each at packed two single pulse[25]. They receive each other, and the CREs and F-15s receive them both. This slot group is not relayed, and it might be required. That way the Rivet Joint could relay for the E-3 and visa versa. Relay requirements should be specified by the network manager.

Slot group 11 represents the transmission of surveillance by the CREs, 32 s/f to each at packed two single pulse. Surveillance reporting requirements are specified for the CREs just as for the block 30/35 E-3. This is relayed by the E-3 in slot group 12 so the CREs can receive each others track data. The F-15s do not receive the relay of the CREs assuming they'll be within line of sight, at least whenever the CRE information is important. This frees up 64 s/f during which the F-15s can be doing something else on a different net (e.g., fighter-to-fighter NPG 19).

Slot group 13 represents the exchange of mission management/weapons coordination (NPG 8) in which engagement status is transmitted with 4 s/f assigned to the E-3 and two CREs at packed two single pulse. 4 s/f is selected by the AF JNDF by experience/guidelines. It need not be specified by the manager. Rivet Joint does not control fighters and so does not transmit in NPG 8. Slot group 14 is the relay by the E-3.

Slot group 15 is the control uplink from the three controlling units. All are assigned the same time slots and they are stacked (i.e., each controlling unit on its own net). To permit all three participants to receive a dedicated assignment (not normally done), the

[23] Typically, s/f equal to the # of tracks for standard packing, ½ the # of tracks for packed two and ¼ the # of tracks for packed four.
[24] The maximum number of tracks which can be reported at the nominal 12 second reporting rate
[25] Admittedly, a very large assignment for the Rivet Joint.

CONNECTIVITY MATRIX EXAMPLE

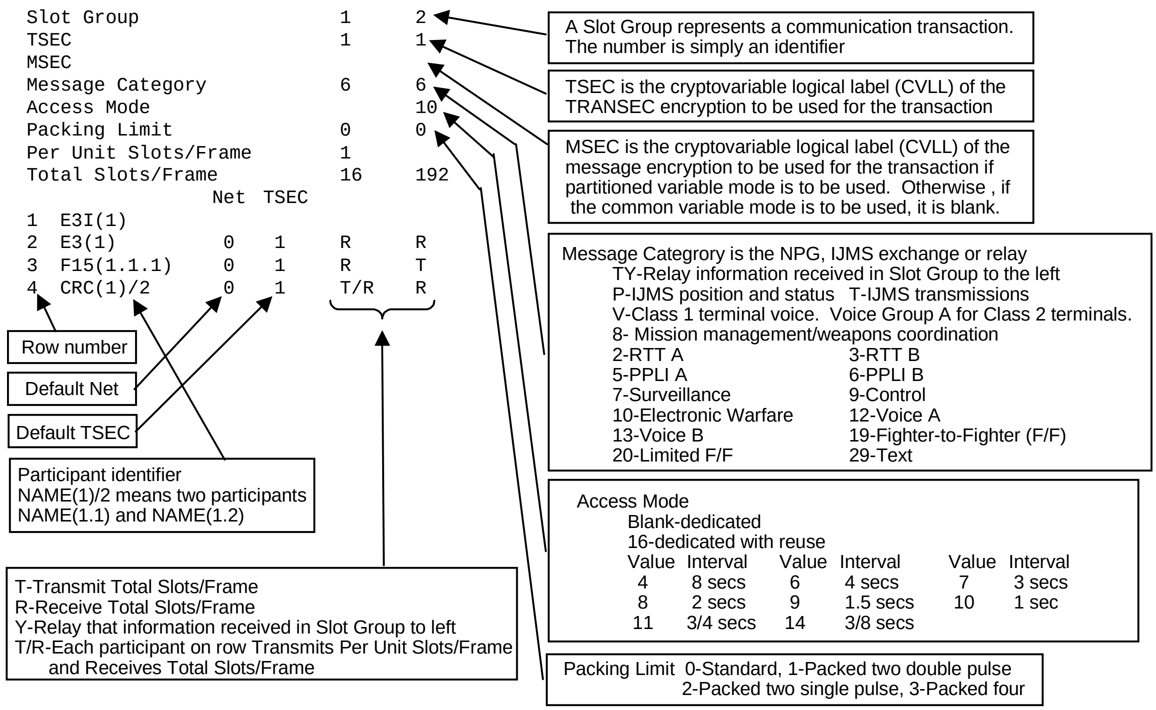
	NET	TSEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SLOT GROUP			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
TSEC			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
MSEC																				
MESSAGE CATEGORY			P	P	T	T	V	3	6	TY	6	7	7	TY	8	TY	9	9	19	20
ACCESS MODE				7				4			8						16	8	14	14
PACKING LIMIT									2		2	2	2		2		2	0	2	2
PER UNIT SLOTS/FRAME			1						1			32	32		4					
TOTAL SLOTS/FRAME			16	96	128	64	128	16	16	16	96	64	64	64	16	16	16	64	160	96
E3I(1)			T/R	R	T	R	T													
E3(1)	0	1					T	T	T/R	Y	R	T/R	R	Y	T/R	Y	T	R		
CRC(1)/2	0	1					T	T	T/R	R	R	R	T/R	R	T/R	R	T	R		
RJ(1)	0	1	T/R		R	T	T	T	T/R	R	R	T/R	R	R	R	R				
F15(1.1.1)	0	1	R	T	R		T	T	R		T	R	R		R		R	T	T	T

4.6-8 Network Management I – Connectivity Matrix

computer aid requires entry of 16 as access code. It means dedicated access but with more than one user. 16 s/f is normal for the control uplink. Slot group 16 is the control backlink assigned to the F-15s with contention access at standard double pulse. It too is stacked. The Rivet Joint is not a controlling unit. The size of the backlink can be estimated by the design facility given the number of fighters intended to be using the network.

Slots groups 17 and 18 represent the two fighter-to-fighter exchanges, NPG 19 with the main cryptokey assigned CVLL 1, and NPG 20 with a second cryptokey assigned CVLL 2. Both are assigned with contention access. The time slots are assigned based on contention pool analysis and experience.

This completes the matrix and fully specifies the network design. Electronic warfare (EW-NPG 10) is not assigned since the E-3 and Rivet Joint do not currently make effective use of exchanged EW information, and the CREs and F-15s do not process EW.



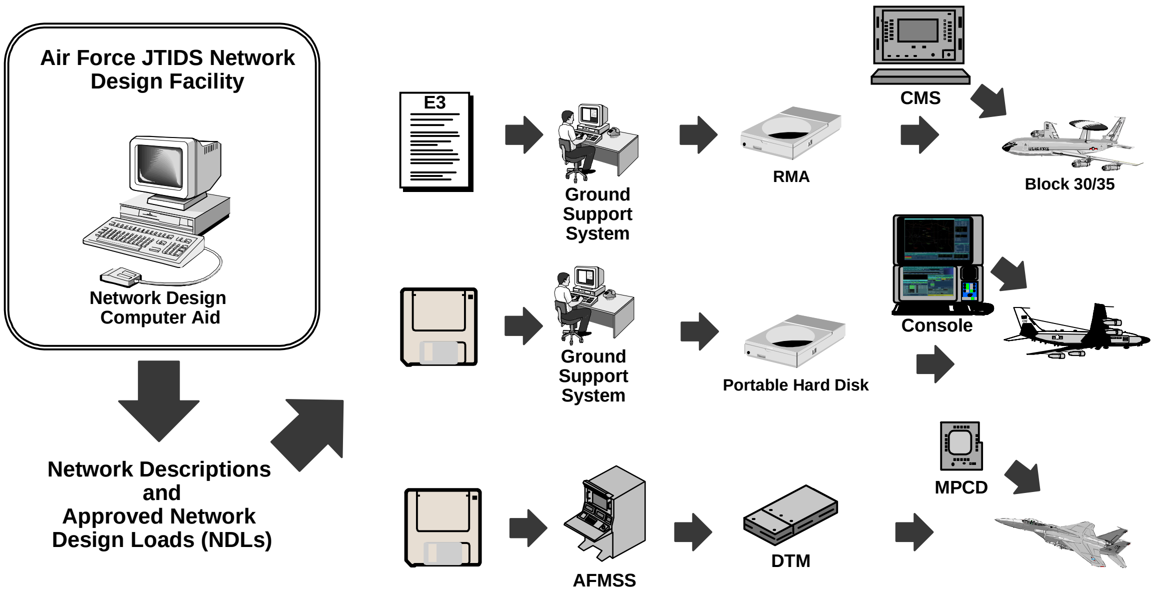
4.7 Network Management I – Network Requirements

The figure provides an abbreviated cheat sheet for the connectivity matrix. It includes the most often used elements for Air Force operations.

The AF JNDF web site includes a network request form to aid the network manager in making a network request. This includes the wing/unit manager when acting as a network manager for daily training. However, the requirements as developed herein with reference to the connectivity matrix are summarized here to assist as well.

- The frequency assignment under which the network will be operated, or at least the requirements and constraints from the frequency assignment;
- The requirement for the extended range mode, if there is one;
- The network participants;
- The disposition of participants (a geographical layout) and the associated relay requirements, or at least the relay requirements;
- The voice requirements
- The surveillance requirements. For the E-3 and CRC/CRE this amounts to the anticipated number of air tracks that will have to be reported. For the Rivet Joint the requirement should be in terms of the two scenarios (i.e., low intensity conflict/training and high intensity conflict).

This list should be adequate for the training networks with which the wing/unit manager will be concerned. The request is further simplified if it can be specified as a change to an existing network.



4.8-1 Network Management I – Network Distribution

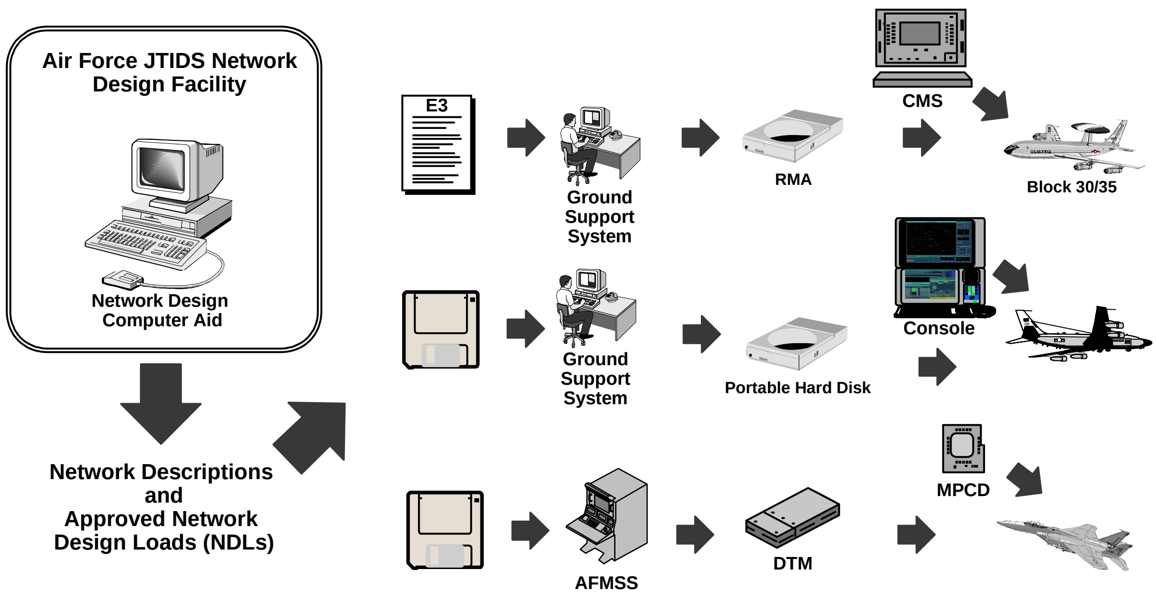
Once designed the network is given a name and distributed or made available to all potential users. The network name has an agreed upon format. That format is given at the AF JNDF web site. The most used elements are given below for use in this document. However, the wing/unit manager should reference the web site for the complete and most current information.

The name is nine characters long, however the center character is not for joint or allied use. The Air Force has its own use for the center character, and it will be discussed in the navigation section. It only applies to F-15s. The naming convention is as follows:

- Characters 1 and 2 – Network owner (e.g., AN-US Navy, AF-US Air Force, AJ-US Joint, NA-NATO, ...)
- Character 3 – Originating network design facility[26] (e.g., B-US Air Force, D-US Navy, N-NATO, ...)
- Character 4 – Network use/environment (e.g., D-wartime, E-exercise, U-training, O-operations, ...)
- Characters 6, 7 and 8 – Three numbers used as a network identifier starting with 001
- Character 9 – One letter as a network version, starting with A.

New networks with the same owner from the same design facility for the same purpose will receive the next identification number is sequence. If the network is intended to replace an existing network (i.e., is serving the same use as the existing network, perhaps being a modification to the existing network), it will keep the same identification number and receive the next sequential version letter (e.g., replacing AFBO0013A with AFBO0013B).

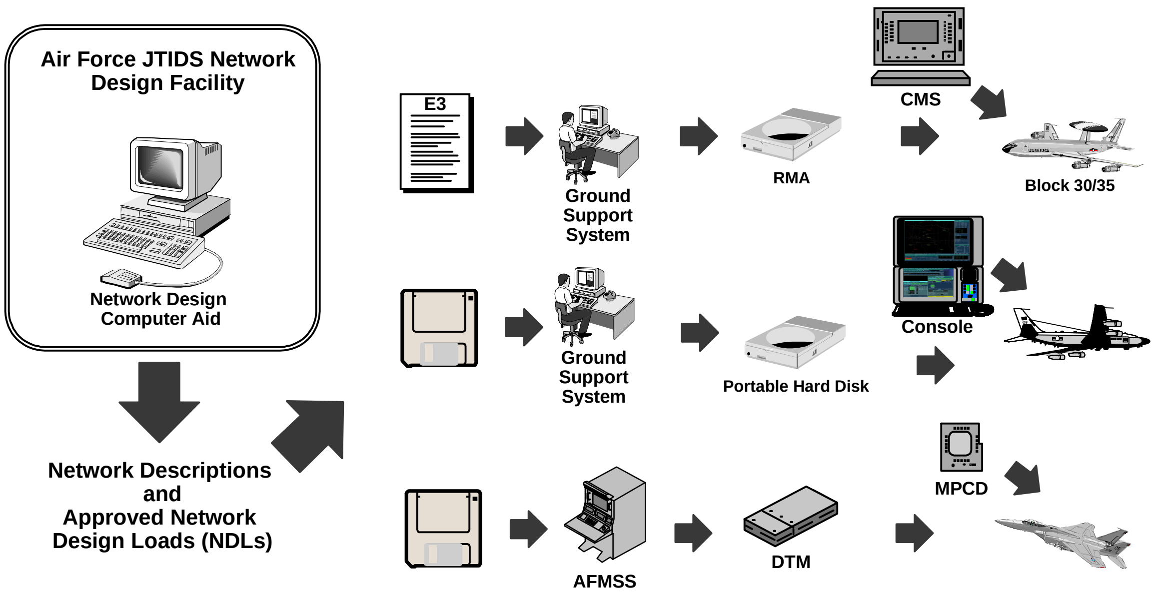
[26] Of the network design, not the network description and NDLs. The source of the network description and NDLs for Air Force platforms will always be the AF JNDF.



4.8-2 Network Management I – Network Distribution

The network will also be dated. The Air Force has its own unique way of using this date. For most services the date is the date that the network was designed. For them the date is redundant to the network name since the network name uniquely establishes the network However, for the Air Force, the date will only start out as the date the network was designed. Date may subsequently change. It is easiest to explain why with an example.

Suppose the AF JNDF coordinates on an allied network involving the US Navy, US Army, UK and French. The network (e.g., NANO0005A dated 04 March 98) is distributed and put into operation as part of a military operation other than war (MOOTW). Now suppose we learn that the initialization parameter in the F-15s which indicates cable delay (i.e., the path length from the F-15 antenna to the terminal) has been set incorrectly and is impacting on the F-15s navigation performance. This parameter is set as part of the integration of the terminal into the F-15 and is fixed in the NDL (i.e., it does not change from network to network). How do we issue new NDLs for the F-15s? We could use a new network name (i.e., increment the version letter), but this will impact on all the platforms of all the services, needlessly. Therefore, the Air Force will use date. The AF JNDF will issue a new network with the same name, but with an updated date. In that network the cable delay for the F-15 NDLs will be corrected. In addition, the AF JNDF web site will include a network update history by date (e.g., NANO0005A, origination date 04 March 98, updated for F-15s only on 3 June 99, updated for Rivet Joint only on 22 July 99). In the example, most Air Force platforms can use the original network dated 04 March 98, but the F-15s must use the NDLs from the updated network dated 3 June 99, and the Rivet Joints must use the NDLs from the updated network dated 22 July 99. Wing/unit managers must ensure that their platforms are using NDLs from the network with a date which is suitable for them. He will determine this from the AF JNDF web site.



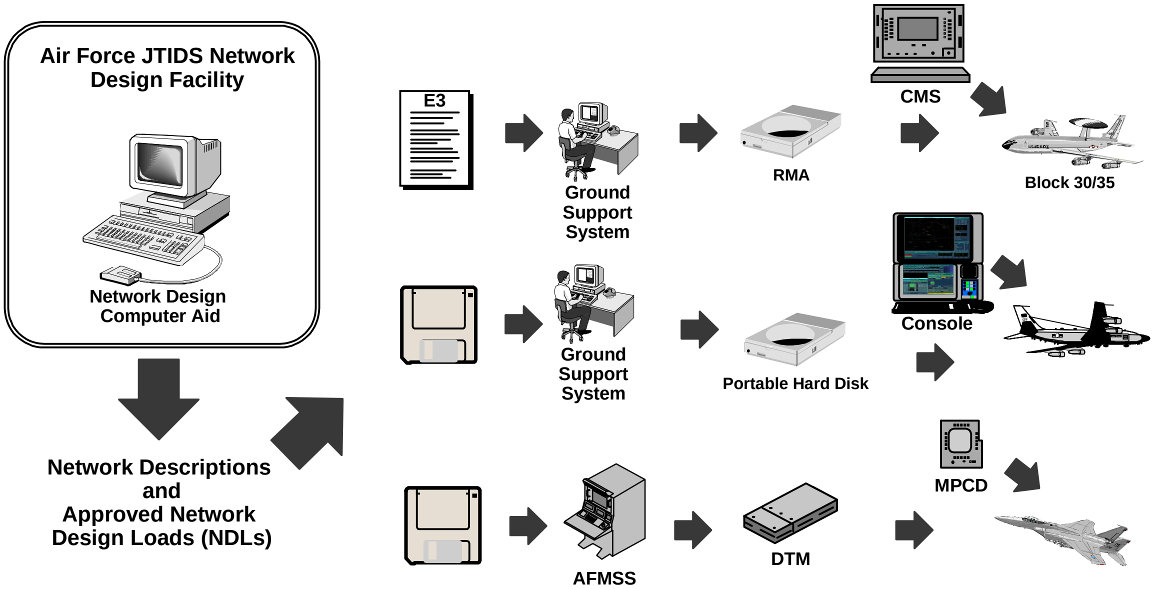
4.8-3 Network Management I – Network Distribution

In general, the wing/unit managers should access the AF JNDF web site weekly and down load any new or modified networks. The network will consist of a description and NDLs. The manager should have a notebook for the descriptions. How he handles the NDLs will depend upon the platform type. Each platform type has its own means for obtaining, storing and using the NDLs. However, independent of how he handles NDLs, the manager should carefully configuration manage his local JTIDS network library.

The block 30/35 E-3 will receive its NDLs three ways. First, it can receive a form which is set up to support manual entry via their ground support system. Up to 100 NDLs can be placed on the Removable Media Assembly (RMA-i.e., a removable hard disk) and taken to the aircraft for use. Each NDL is simply given a reference sequence number (i.e. 1, 2, 3, ...) which must be associated with network name and participant identifier (e.g., NANO0005AE31) using a separate list. This approach to initialization is currently used and is depicted in the figure. Second, it can receive the NDLs on a DOS diskette termed the network floppy disk (NFD). For the E-3 the NDLs are delivered in the same format as the file which is created by the ground support system when the NDL is entered manually. This was intended to avoid the need for manual entry. It has been demonstrated, but requires a PC to be associated with the ground support system, which is not normally the case. The third way is to receive a form which is set up to support manual entry on the aircraft via the control monitor set (CMS). This is labor intensive[27], but sometimes required.

The block 20/25 E-3 can only receive its NDLs via a form, in its case using the Radio Set Control (RSC) device to enter the data on the aircraft. However, for the Class 1 terminal equipped E-3 the amount of initialization data in the NDL is much less than that for the Class 2 terminal of the block 30/35 E-3, and so its manual entry is not unreasonable.

[27] e.g., up to 45 minutes to enter a NDL.



4.8-4 Network Management I – Network Distribution

The Rivet Joint receives its NDL via the network floppy disk. The diskette is read by the ground support system and the NDLs placed on a portable hard disk which is taken to the aircraft. The support system operator can (and should) name each load using network name concatenated with participant identifier (e.g., NANO0003ARJ1). The number of NDLs which can be stored on the hard disk is, for all practical purposes, unlimited. If necessary, the diskette can be carried to the aircraft and loaded onto the hard disk. The Rivet Joint wing manager should carefully configuration manage the diskettes for the networks in his local JTIDS network library.

The F-15 receives its NDL via the network floppy disk. The diskette is read by the Air Force Mission Support System (AFMSS) and stored in a library of up to 50 networks[28]. The pilot can load up to two NDLs on his data transfer module (DTM) which is then taken to the aircraft and from which the terminal is loaded. The NDL name referenced is network name concatenated with participant identifier (e.g., NANO0003AF151.1.1). The F-15 wing/unit manager should carefully configuration manage the diskettes for the networks in his local JTIDS network library. These should include those stored on the AFMSS, since that device could fail, and those which may not fit on the AFMSS.

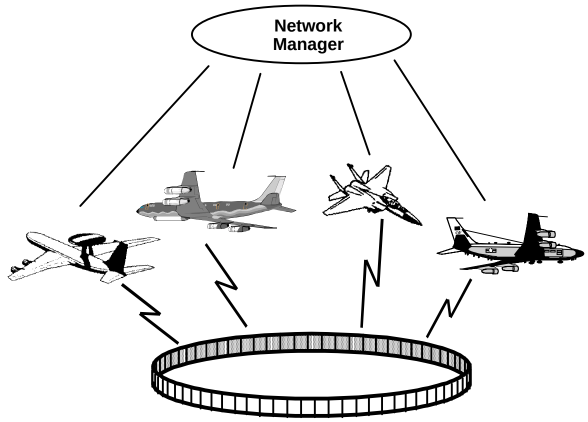
[28] Each network can have up to 64 F-15 NDLs.

CURRENT NETWORK NAME	E3I	E3	E8	ABCCC	RJ	MAOC	F15	CRCI	CRC	BN	FAAD	REMARKS
AFBD0001A	4		1	1								
AFBE0002A	1					1	1				3	
AFBE0004A		1	1	1	1		2*					
AFBT0003A	2	1									2	

NOTE: "*" see description document for specific platform and interface designation

4.9 Network Management I – Network Selection

Once a JTIDS network library is established, the network manager, including the wing manager acting as network manager for training networks, can choose a network and operate it. All networks in which Air Force platforms can participate are on file on the AF JNDF web site with the possible exception of some recent designs which have been e-mailed to the users intended to use them initially and which have not yet been posted on the web site. The networks are listed in a selection matrix. A piece of the matrix is shown in the figure for illustration purposes. The manager can look at the names and determine the intended use for the network (i.e., character four), and the matrix gives the platforms involved. This permits the manager to quickly select a subset of suitable networks (or deduce that he needs a new network). Each potentially suitable network must then be looked at in detail via their descriptions. The descriptions include the connectivity matrix.



4.10 Network Management I – Changing Packing Limits

In the modes of operation section, we discuss packing limits for NPGs. The network manager, including the wing manager acting as network manager for training networks, should be cognizant of the packing limits in use via the connectivity matrix and the impact of multinet, interferometer effects and jamming on single pulse packing limits. He should also be cognizant of any frequency assignment constraints[29] on the alteration of packing limits, and the impact of packing limit changes on transmit capacity. If feedback from operators indicates that single pulse performance is unacceptable, the manager can decide to alter packing limits for the E-3 and/or Rivet Joint. For example, if they have been assigned packed four single pulse for their surveillance transmissions, the manager may decide to change them to packed two double pulse. This will not change the number of pulses in the network and so will not impact on frequency assignment constraints, but it will cut the surveillance transmit capacity for the aircraft in half.

As another example, the network may be designed with the E-3 and Rivet Joint surveillance at packed two single pulse to minimize the number of pulses per time slot. The number of total pulses in an area is one of the frequency management constraints[30]. Suppose that multipath effects are found to be severe, and it is desired to go to double pulse. The packing limit for surveillance can be changed to standard double pulse, cutting the surveillance transmit capacity in half without increasing the number of pulses per time slot. But this reduction may not be acceptable. It may be desirable to change the packing limit to packed two double pulse. However, this does increase the number of pulses per slot from 258 to 444, and the frequency management constraints may not permit this. Therefore, packing limit changes during any operation other than a war[31] should be coordinated with the network manager.

This coordination can be done by voice while the operation is in effect if it is available to the manager. It can be done informally at mission prebriefs. It can also be done via the OPTASK LINK.

[29] These will be covered in detail subsequently in the frequency management section.
[30] And will be discussed in detail in a subsequent section.
[31] In which the frequency management constraints have been waived.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/-/E3.1/-/-/-/-/-/-//
JUDATA/726 ACS:CRC:BLUEBOY/-/CRC.1/-/-/-/-/-/-//
JUDATA/255 ACS:CRC:REDTOP/-/CRC.2/-/-/-/-/-//
JUDATA/97 IS:RC-135:VACUUM/-/RJ.1/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:HOGGER/-/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/-/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

4.11-1 Network Management I – OPTASK LINK

Once a network is selected it can be coordinated with the participants. This involves the use of the OPTASK LINK message. The OPTASK LINK message is a member of the US message text format series. The format is given in MIL STD 6040 and is available on the Defense Information Systems Agency (DISA) Center for Standards web site[32]. An OPTASK LINK message treats all tactical data links, but this manual will discuss only the Link 16 portion, and then only that portion directly involved in setting up and operating the network (i.e., not TADIL J filters).

An example OPTASK LINK message is depicted in the figure. This OPTASK LINK will be explained in this and in subsequent sections. The message is comprised of a sequence of data sets. Each data set starts with an identifying set identifier (SETID). The example is unclassified. Operational OPTASK LINK messages are classified. However, units may decide that training networks may be supported by unclassified OPTASK LINK messages which will permit their distribution via e-mail. The first SETID is MSGID (message identifier) and this message is the OPTASK LINK. It has been prepared by the 552 ACW (originator) and is the first (sequence number) such OPTASK LINK prepared by the 552 ACW in the month of July. The second SETID is PERIOD (period of operation, in this case for the OPTASK LINK since it follows the OPTASK LINK message identifier) which is from the 15th of July at 08:00 Zulu to the 24th of July at 22:00 Zulu. The third SETID (i.e., LNKXVI/16//) indicates that the following section of the OPTASK LINK pertains to Link. The fourth SETID is a repeat of PERIOD giving the period of applicability of the Link 16 section since it follows the LNKXVI/16// SETID.

Skipping[33] to the eighth SETID we have the network name (i.e., NETWORK/AFBO0013A/-[34]//). If the AF JNDF has found it necessary to change an Air Force platform-only parameter and has issued the revised NDLs for that platform type using

[32] http://www.itsi.disa.mil/
[33] The grayed SETIDs will be discussed subsequently
[34] Some of the dashed elements will be discussed subsequently, certainly all that are compulsory.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/-/E3.1/-/-/-/-/-/-//
JUDATA/726 ACS:CRC:BLUEBOY/-/CRC.1/-/-/-/-/-/-//
JUDATA/255 ACS:CRC:REDTOP/-/CRC.2/-/-/-/-/-//
JUDATA/97 IS:RC-135:VACUUM/-/RJ.1/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:HOGGER/-/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/-/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

4.11-2 Network Management I – OPTASK LINK

date for configuration management, the date of the NDL which should be used by a platform of that type will be more recent than the date of the original network design.

The JUDATA SETID is used to associate actual platforms with generic network participant identifier. For example, in the first JUDATA line, the E-3 of the 964 ACS with voice call sign Magic is assigned the E3(1) network design load (NDL) from AFBO0013A. For F-15s the format will depend upon which access mode is being used. If dedicated access is used, each F-15 will require its own NDL, i.e. its own participant identifier. This is depicted in the 5th and 6th JUDATA lines. We are operating two four-ship flights from the 390 FS, Hogger and Eagle. Hogger flight will use NDLs associated with participant identifiers F15(1.1.1), F15(1.1.2), F15(1.1.3) and F15(1.1.4), probably F15(1.1.1) to Hogger 1[35], the flight lead; F15(1.1.2) to Hogger 2, his wingman; F15(1.1.3) to Hogger 3, the second element lead; and F15(1.1.4) to Hogger 4, his wingman. But the specific aircraft assignment is up to the 390 FS. If contention access is used, several or all of the F-15s may be assigned the same participant identifier (e.g., to assign all the fighters of Eagle flight the NDL F15(1.1.1) we indicate JUDATA/390 FS:F-15C:EAGLE/-/F15.1.1.1/-/-/-/-/-/-/-//).

The JSTNETS is used to associate groups of participants with net numbers for the stacked net NPGs. The first JSTNETS SETID is for the control NPG (i.e., /CNTRL/) which is NPG 9 (i.e., /9/) for which we designate the air control by the E-3 with voice call sign Magic (i.e., /MAGIC AIR CONTROL/) to take place on net 1 (i.e., /1/), the air control by the CRE with voice call sign Red Top (i.e., /REDTOP AIR CNTRL/) to take place on net 2 (i.e., /2/), etc. This SETID would wrap on additional lines if many controlling units were present. The second JSTNETS SETID is for voice group A (i.e., /VGA/) which is NPG 12 (i.e., /12/) for which intra C^2 voice (i.e., /C2 VOICE/) will take place on net 0 (i.e., /0/), intraflight voice for Hogger flight (i.e., HOGGER VOICE) will take place on net 1 (i.e., /1/), etc. The last JSTNETS SETID is for the fighter-to-fighter exchange (i.e., /NCNC[36]/) which

[35] flight leads voice call sign
[36] The fighter-to-fighter exchange is formally termed nonC^2 to-nonC^2.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/-/E3.1/-/-/-/-/-/-//
JUDATA/726 ACS:CRC:BLUEBOY/-/CRC.1/-/-/-/-/-/-//
JUDATA/255 ACS:CRC:REDTOP/-/CRC.2/-/-/-/-/-//
JUDATA/97 IS:RC-135:VACUUM/-/RJ.1/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:HOGGER/-/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/-/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

4.11-3 Network Management I – OPTASK LINK

is NPG 19 (i.e., /19/) with all F-15s (i.e., F15 FTR-TO-FTR) operating on net 1 (i.e., /1/).

The impact of multinet, interferometer effects and jamming on single pulse packing limits may cause the operators and network manager to decide to change the packing limits on the E-3 and/or Rivet Joint. This coordination can be done by voice while the operation is in effect if it is available to the manager. It can be done informally at mission briefs. It can also be done via the OPTASK LINK. However, there is no specific SETID for doing it. It can currently be done using a general text SETID. For example,

GENTEXT/964 AWACS:E-3:MAGIC SHOULD CHANGE SURVEILLANCE (NPG 7) PACKING LIMIT FROM 3[37]-PACKED FOUR SINGLE PULSE TO 1-PACKED TWO DOUBLE PULSE TO MINIMIZE OBSERVED MULTIPATH EFFECTS. REDUCTION IN SURVEILLANCE TRANSMIT CAPACITY TO BE ACCOMODATED WITH LENGTHENED TRACK REPORTING INTERVALS.//

There is a good deal of latitude given by MIL STD 6040 in composing the OPTASK LINK message. It should be referenced when reading and, in particular, writing one. But this example, should go a long way toward permitting the wing/unit manager to use the OPTASK LINK. It will be further expanded upon in subsequent sections.

[37] Numeric codes for packing limit are utilized (0-standard, 1-packed two double pulse, 2-packed two single pulse, 3- packed four single pulse).

In garrison responsibilities in support of operations managed by personnel other than at wing:

1. Maintain local JTIDS network library (JNL) taken from AF JNDF web site weekly and maintained in a notebook and, if appropriate, on diskette (one network per diskette labeled and dated). Reference: para 4.3

Network manager responsibilities for daily training network operations:

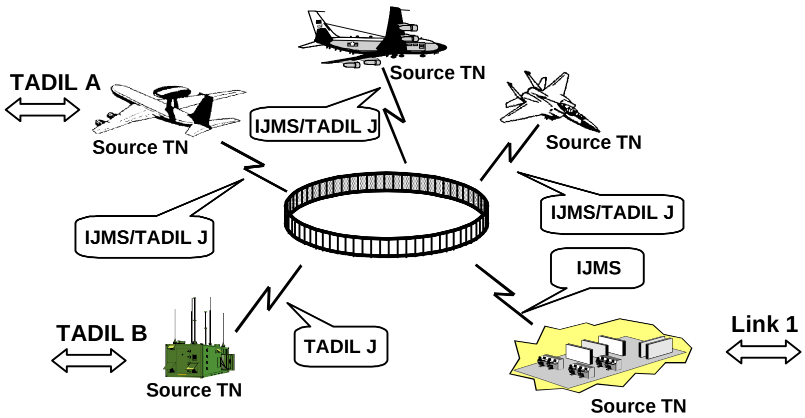
1. If necessary, request Air Force-only training networks from the Air Force JTIDS Network Design Facility (AF JNDF) and joint and allied training networks from the JTIDS Network Design Library (JNDL). Use the form on AF JNDF web site and/or the network request items from this manual. Coordinate requests for joint/allied networks with AF JNDF. Reference: para 4.5
2. Select network from Air Force JNL and task individual platforms via NETWORK SETID of the OPTASKLINK. Tasking may be informal, but use of the OPTASK LINK is strongly recommended, where appropriate, to become experienced with its use. Example NETWORK/AFBO0013A/-//.Reference: para 4.11-1
3. Associate individual participants with the appropriate network design load (NDL) via participant identifier in the JUDATA SETID of the OPTASKLINK. Example, 965 AWACS E-3 call sign Magic use NDL for E3(1), i.e., JUDATA/964 AWACS:E-3:MAGIC/-/E3.1/…...Reference: para 4.11-2
4. Define use of stacked nets. Example voice A net 0 for C^2 platform use, net 1 for Hogger flight, net 2 for Eagle flight. Control net 1 for E3(1). Fighter-to-Fighter (F/F) net 1 used by all F-15s. Distribute via JSTNETS SETID in the OPTASK LINK, i.e., JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1//.Reference: para 4.11-2
5. Be cognizant of the packing limits in use and the impact of multinet, interferometer effects and jamming on single pulse packing limits. Also be cognizant of any frequency assignment constraints on the alteration of packing limits, and the impact of packing limit changes on transmit capacity. Coordinate changes to packing limits if conditions warrant and constraints permit.Reference: para 4.11-3

4.12 Network Management I – Wing/Unit Manager Checklist

This completes the initial description of the duties of the wing/unit manager. We will summarize the duties alluded to in a checklist. Then, as additional duties are described in subsequent sections, the checklist will be expanded, being completed with the Network Management II section.

The checklist is separated into the in garrison duties of the wing/unit manager for deployed operations, and the additional duties when he is acting as network manager for training networks involving his platforms and, possibly, platforms deploying to train with his platforms.

5.0 Track Numbering



5.1-1 Track Numbering – Multi-TADIL Operations

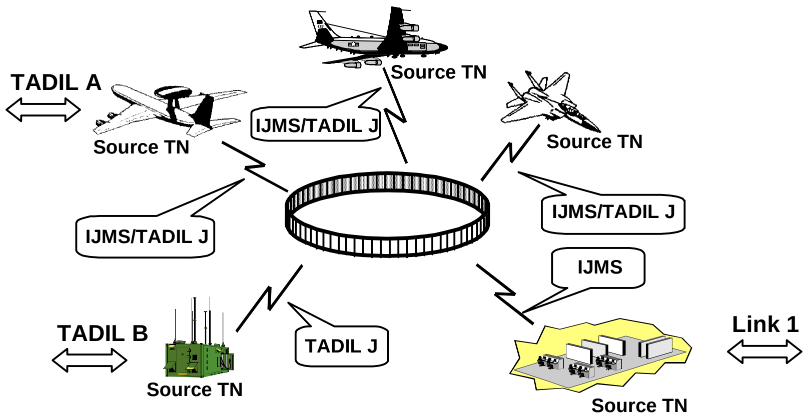
All Link 16 participants transmit a Precise Participant Location and Identification (PPLI) message. To uniquely identify themselves they are assigned a TADIL J source track number (STN). In general, STNs consist of five octal[1] digits. Similarly, surveillance platforms transmit tracks, points and certain other data with unique track numbers (TNs) with which to identify them. TNs generally consist of two 5 bit characters followed by three 3 bit (octal) digits. This supports the use of two alphanumerics followed by three octal digits and the use of five octal digits, the latter by using only the three lower order bits of the first two fields. Each surveillance platform is assigned a unique block of TNs from which it will draw values to use to report out tracks, points, etc. <u>The wing manager, when acting as JTIDS/Link 16 network manager for training networks, will be responsible for the assignment of STNs and TN blocks.</u>

There are conventions for assigning STNs and TNs which should be followed. These conventions are related to the operation of other tactical data links, and to the assignment of source and track identification numbers for the reporting of tracks, points and other data on those data links. So these items are discussed a bit before proceeding further with STN and TN assignment conventions.

The figure depicts a multi-TADIL network. TADIL A, also called NATO Link 11, is a broadcast radio frequency (RF) data link, much like Link 16 but with much less capacity and no jam resistance. TADIL B is a point-to-point data link which uses the same messages as TADIL A. It is termed NATO Link 11B. NATO has its own point-to-point data link system termed NATO Link 1. These data links are for C^2 platforms, not fighters. The E-3 and Rivet Joint are TADIL A capable. The CRC/CRE is TADIL A, TADIL B and Link 1 capable.

Some JTIDS and all MIDS terminals can operate both TADIL J and IJMS. A JTIDS/MIDS network can contain both an IJMS and a TADIL J segment. Since the TADIL J and IJMS messages are incompatible, this situation looks very much like two tactical data

[1] Numbers with base 8 rather than the normal base 10.



5.1-2 Track Numbering – Multi-TADIL Operations

links (i.e., IJMS and TADIL J) using the same exchange medium (JTIDS/MIDS). This results in a somewhat complex situation for the platforms employing a translating bilingual terminal (e.g., the F-15, Rivet Joint, JSTARS, ABCCC, ...). It is made more complex by the fact that the CRC/CRE is not bilingual, and can operate only TADIL J. With the full conversion of the E-3s from the Class 1 JTIDS terminals (block 20/25 E-3s) to the Class 2 JTIDS terminals (block 30/35 E-3s) such mixed operations will not be required in US-only and some allied networks. However, the NATO Air Defense Ground Environment (NADGE) will retain Class 1 JTIDS terminals through at least 2005, and some IJMS will continue to be used when operating with NADGE sites. The platform using Link 1 in the figure represents a NADGE site. We'll discuss mixed IJMS/TADIL J operations a bit too.

A multi TADIL network is managed by the Interface Control Officer (ICO). If its a joint network, he/she[2] is referred to as a Joint Interface Control Officer (JICO). Multi TADIL operations are governed by the Joint Multi TADIL Operating Procedures (JMTOP)[3]. The ICO will either act as Link 16 network manager[4] or designate a subordinate Link 16 network manager. The ICO will distribute an OPTASK LINK which covers all TADILs including Link 16. Daily training networks can be JTIDS/Link 16 involving only TADIL J and/or IJMS, or may involve other TADILs (i.e., TADILs A and/or B).

This document cannot hope to treat ICO functions in general. The JMTOP is an extensive document and JICO training is provided by the Joint Multi TADIL School (JMTS) at FORSCOM in an intensive three-week Multi TADIL Advanced Joint Interoperability (MAJIC) course. However, we will treat the other TADILs enough to assist the wing manager in dealing with the simple multi TADIL networks he may be involved with for daily training. <u>If the wing manager is going to be involved heavily in multi TADIL networks for daily training, he should obtain formal JICO training at the JMTS</u>.

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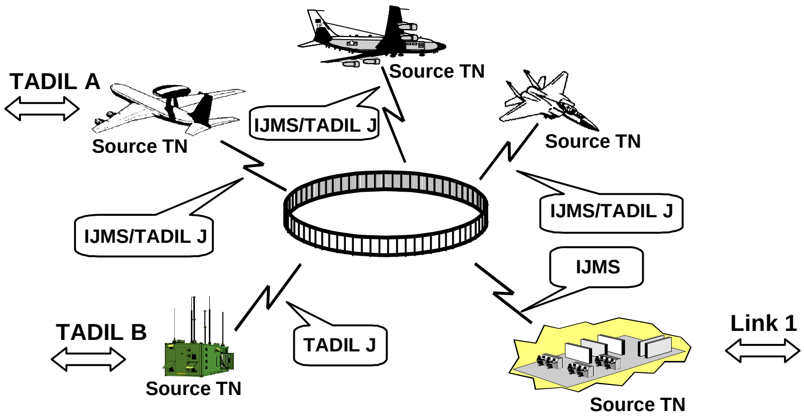
[2] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.
[3] CJCSM 6120.01A dated 24 October 1997.
[4] Formally called the TADIL J Manager in the JMTOP



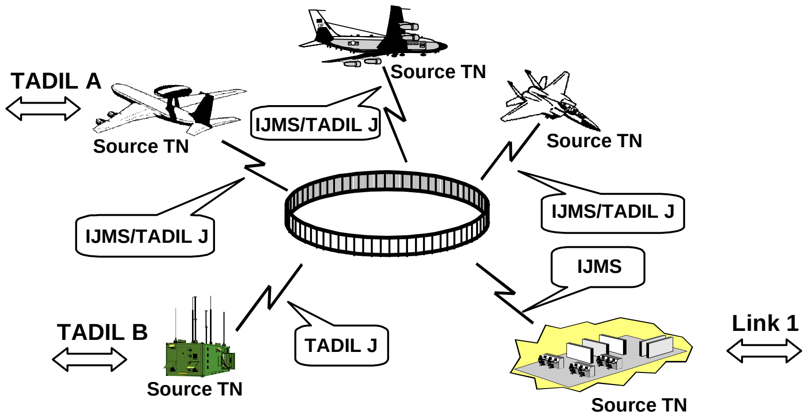
5.1-3 Track Numbering – Multi-TADIL Operations

C^2 units which operate TADILs for daily training within the US&P do so within one of several air defense regions/sectors (e.g., northeast, southeast, Caribbean and western). The associated regional/sector operations centers (R/SOCs) perform the ICO function for multi TADIL training operations and issue a standing[5] OPTASK LINK message governing TADIL operations in their area. As of the preparation of this document the point of contacts (POCs) for the CONUS R/SOCs are:

- Northeast Sector Operations Control Center (NESOCC), Office Symbol DOCT; Rome NY; OPTASK LINK DSN 587-6802, Related Briefing x 6854
- Southeast SOCC (SESOCC), Office Symbol DOCD; Tyndal AFB, FL; OPTASK LINK DSN 523-5553, Related Briefing x 5105
- Caribbean Regional Operations Center (CARIBROC), Office Symbol J37; Key West, FL; OPTASK LINK DSN 483-2055, Related Briefing x 3113
- Western Air Defense Sector (WADS), Office Symbol DOCO; McChord AFB, WA.; OPTASK LINK DSN 984-4729, Related Briefing x 4668

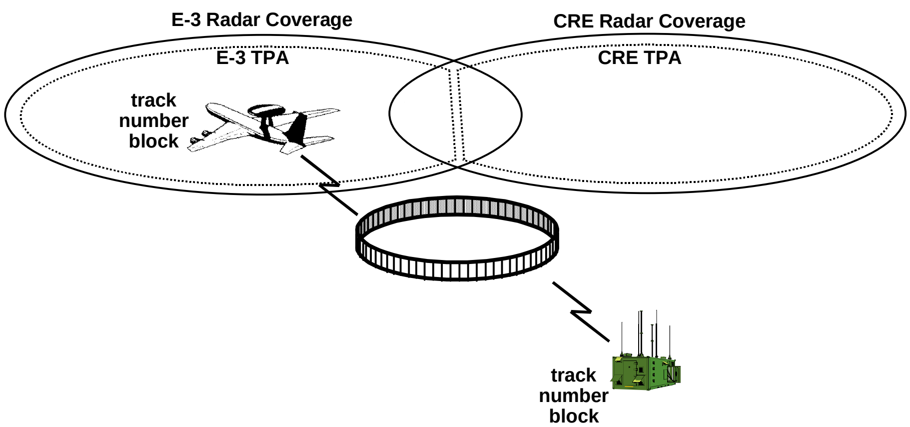
One on the functions of the ICO is the assignment of unique source identification numbers for the platforms participating on the TADILs (e.g., Link 16 STNs) and track numbers for the identification of reported tracks (e.g., Link 16 TNs). As previously mentioned, STN and TN block assignment will be the responsibility of the wing manager when managing a daily training network. If operating a stand alone JTIDS/Link 16 network without TADILs A or B, the wing manager can assign his own identifiers using a set of assignment conventions. However, if operating his Link 16 network as part of a multi TADIL network which is using the standing OPTASK LINK associated with his region/sector, his identifier assignments will have to “fit in” with those of the standing OPTASK LINK. This will be a normal mode of operation, particularly as the CRC/CRE becomes equipped with Link 16.

[5] Fairly static.



5.1-4 Track Numbering – Multi-TADIL Operations

One could assume that Link 16 will be incorporated into the R/SOC ICO's duties and the associated standing OPTASK LINK message. However, Link 16 is still new and such procedures have not all been worked out as yet. Therefore, in this document, we will outline procedures with which the wing manager will act as Link 16 network manager, preparing the Link 16 OPTASK LINK for his network, and do so either as a stand alone JTIDS/Link 16 operation or within the constraints imposed by other TADILs (i.e., TADILs A and/or B) as defined by the associated standing OPTASK LINK message. This coordination with the standing OPTASK LINK will impact primarily the assignment of STNs and TNs. However, before presenting the procedures we first need to discuss the use of track numbers.



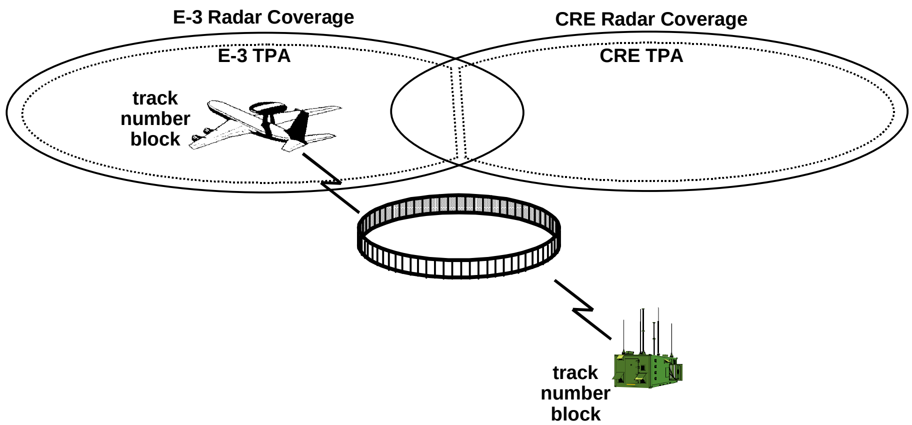
5.2-1 Track Numbering – Reporting Responsibility

In the figure we show an E-3 and a CRE with their overlapping radar coverage areas. For all tactical data links it is intended that only one participant report a track on any one entity. The rules that support this are called reporting responsibility (R^2) rules. There are two approaches to R^2, one based on track quality and one based on non-overlapping geographic R^2 areas called track production areas (TPAs). For quality based R^2,

- The C^2 unit receives tracks being reported by other C^2 units and generates a remote track file.
- The C^2 unit takes radar/sensor hits, forms a local track, establishes a track quality, places the data in a local track file, and correlates local tracks with remote tracks[6].
- If a local track does not correlate, it is reported out on the data link.
- If a local track does correlate and the local track quality is better than that of the remote track (two better in quality), it is reported out on the data link with the same TN with which it is currently being reported, otherwise it is not reported.
- If a C^2 unit is reporting out a local track and it receives a remote track with the same TN of better quality, it stops reporting the track

This process <u>should</u> place only the best quality track on the data link for a given entity, but failed correlation can result in duplicate tracks (i.e., two tracks with different TNs for the same entity).

[6] The E-3 operator should manually correlate the local track with the remote track by initiating the local track as a "monitor track" on the remote track. Then, if the monitor track lies within an acceptable correlation window of the associated remote track, they are deemed to correlate and R^2 can be performed between the two tracks. The Rivet Joint operator manually correlates the local and remote track using a correlate (CORR) function, and this enables the R^2 function.

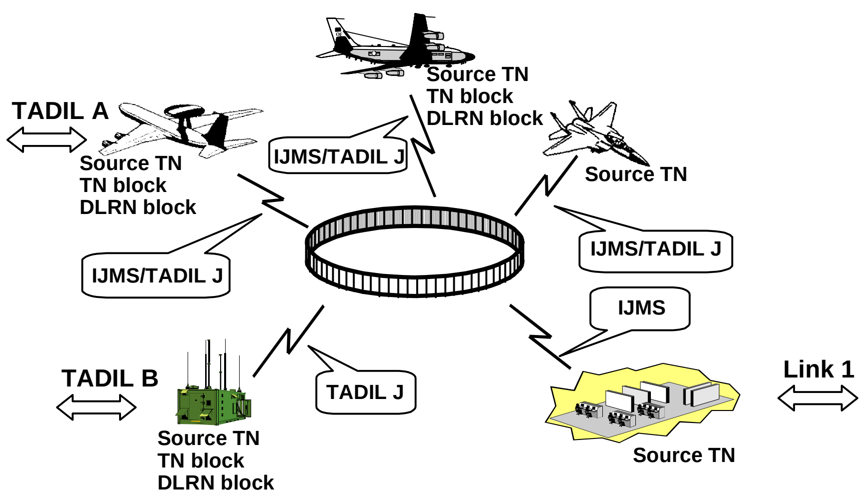


5.2-2 Track Numbering – Reporting Responsibility

For R^2 based on TPAs,

- The C^2 unit is assigned a TPA. Independent of track quality, the C^2 unit reports all local tracks within its TPA. Tracks originating within its TPA will be transmitted with TNs drawn from its TN block.
- The C^2 unit receives tracks being reported by other C^2 units and generates a remote track file.
- At the edge of the TPA, if a local track is exiting the TPA, the reporting C^2 unit will drop the track.
- If the dropped entity was being tracked by another C^2 unit (but not reported, being outside its TPA), the track had been correlated with the track just dropped by that C^2 unit[7], and the track has just entered the C^2 unit's TPA, the C^2 unit should begin to report on the track with the same TN that was being used.

This process <u>should</u> place only one (not always the best) track on the data link for a given entity, but failed



correlation on hand over can result in TN shifts (i.e., the C^2 unit newly reporting the track will not be using the same TN as the C^2 unit formerly reporting the track).

5.3-1 Track Numbering – Data Forwarding and Concurrent Operations

Some C^2 units will operate on more than one tactical data link. These multi TADIL operations will be discussed by example[8] and for the discussion we assume that we're using quality based R^2. In the figure the

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[7] For the E-3, this is done manually by initiating a "monitor track" on the remote track. Then, when the remote track is dropped, the E-3 will begin to report out the track. For the Rivet Joint this is done manually by initiating a track with the proper TN.

CRE is operating on both TADIL J and TADIL B. The CRE is a data forwarder. It will transmit TADIL B tracks it receives from the TADIL B network as TADIL J tracks on Link 16, and it will transmit TADIL J tracks it receives from the Link 16 network as TABIL B tracks on the TADIL B network. The TADIL J participants will be assigned a block of TNs with which to report out the TADIL J tracks they originate. The TADIL B participants will be assigned a block of TADIL B track numbers with which to report out the TADIL B tracks they originate. TADIL B and TADIL A track numbers will be referred to as data link reference numbers (DLRNs[9]) to distinguish them from TADIL J track numbers (TNs). In addition to TNs, each TADIL J unit will be assigned a STN. In addition to DLRNs each TADIL B participant will be assigned a reporting unit[10] (RU) identification number. For the forwarder, the STN will equal the RU number[11]. For other platforms the RU numbers[12] and STNs should all be different so as to uniquely identify them.

<u>The E-3 must be assigned a block of DLRNs before it can report tracks at all, even if it is not operating in a TADIL A network</u>. Also, it will not report out a track on TADIL J if it has used up all of its DLRNs, even if it has unused TNs remaining. So <u>the size of the E-3 DLRN block should be greater than or equal to the size as its TN block</u>. The Rivet Joint must be assigned a block of DLRNs only if it is operating in a TADIL A network. It operates TADIL A and TADIL J independently and so the TN block need not match the DLRN block[13]. In fact, if only operating on Link 16, Rivet Joint requires no DLRN block.

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[8] Concurrent operations and data forwarding are complex operations and will be illustrated here briefly only to explain track block and STN assignment conventions. In the example, the E-3 is a block 30/35 E-3.

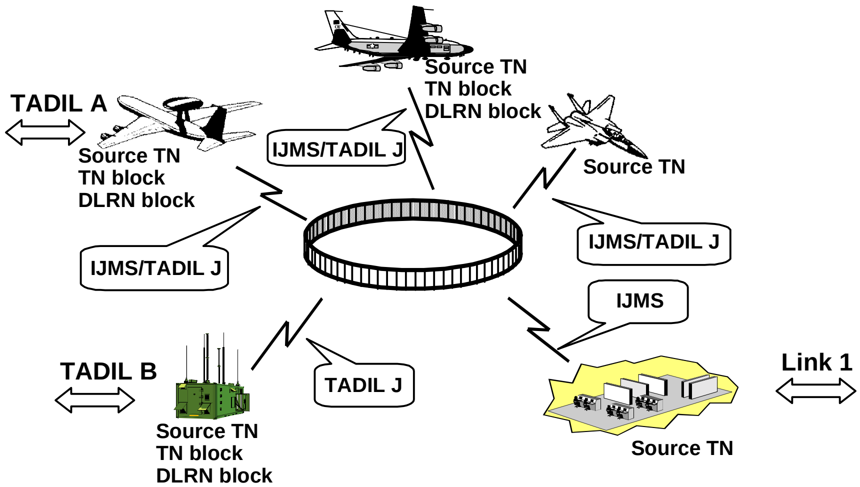
[9] This is Air Force-only terminology.

[10] A unit operating directly on TADIL B. A unit operating directly on TADIL A is called a participating unit (PU) and is given a PU identification number.

[11] For a forwarding PU the STN will equal the PU number.

[12] And for PUs the PU numbers

[13] However, we will subsequently find that the equating of track identification numbers is operationally desirable.



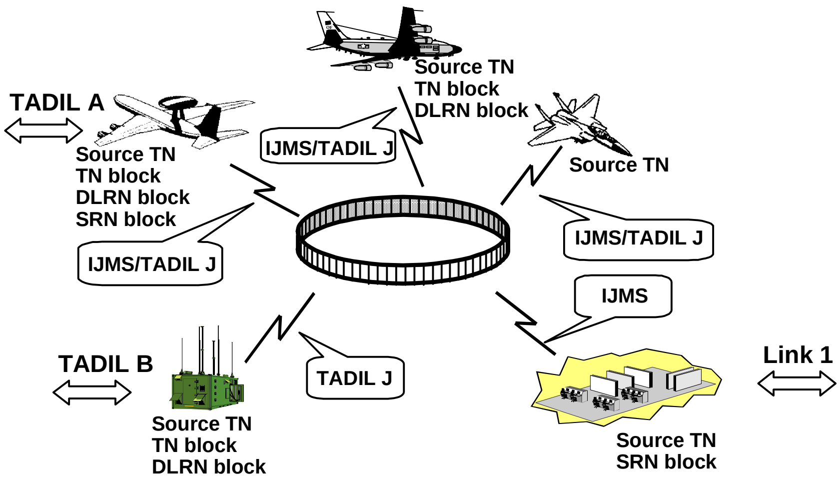
5.3-2 Track Numbering – Data Forwarding and Concurrent Operations

The TADIL B participants will transmit the TADIL B tracks they originate using a DLRN drawn from their DLRN block. In general, the CRE will forward these tracks as TADIL J tracks using a TN drawn from its TN block and, for each TADIL J track, will send a track identity message[14] associating the DLRN with the TN. So all the participants on the Link 16 network can know the DLRN of each forwarded TADIL B track. As it turns out, the E-3 processes the track identity message and so the E-3 operators will know the DLRN. The Rivet Joint does not. We'll come back to this subsequently.

The TADIL J participants will transmit the TADIL J tracks they originate with a TN drawn from their assigned TN block. In addition, the E-3 will assign a DLRN to each of the TADIL J tracks it originates and send a track identity message associating the DLRN with the TN for the track[15]. So all participants on the Link 16 network can know the DLRN for each reported E-3 TADIL J track. The Rivet Joint does not assign a DLRN for each reported TADIL J track nor transmit a track identity message. The CRE will forward the E-3 TADIL J tracks as TADIL B tracks using the DLRN assigned by the E-3 as received via the track identity message. It will forward Rivet Joint TADIL J tracks as TADIL B tracks using a DLRN drawn from its own DLRN block since the Rivet Joint sends no track identity message. It will transmit a track identity message for each Rivet Joint track. The E-3 will process the track identity message, but not Rivet Joint.

Tracks are suppressed in surveillance platforms by their receipt of a PPLI and its correlation with a local track. This is to prevent both a track and a PPLI for the same entity being reported on the link. But the TADIL B participants wish to have a TADIL B track for the Link 16 participants. Therefore, the CRE will forward PPLIs as TADIL B tracks on the TADIL B network. If it can[16], it will equate the DLRN to the STN of the platform's PPLI, otherwise it will use a DLRN drawn from its assigned block. In either case it will assign a track quality commensurate with that of the PPLI.

[14] This need only be sent once, and the association will be "remembered" by each TADIL J participant.
[15] That's why it requires a DLRN block before it will transmit a TADIL J track.
[16] This will be discussed further subsequently.



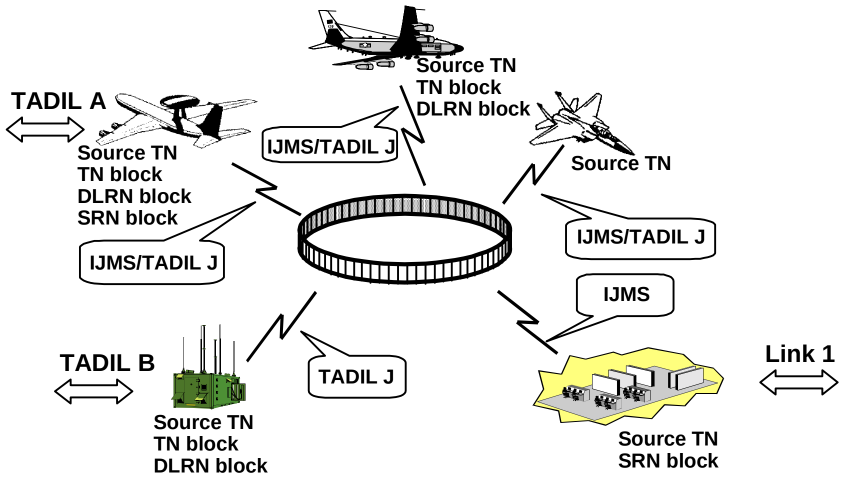
5.3-3 Track Numbering – Data Forwarding and Concurrent Operations

R^2 is performed across the two data links. In performing R^2, a TADIL B unit will correlate its local track with any remote tracks it receives, either directly from TADIL B participants or as forwarded by the CRE. It will report uncorrelated local tracks using a DLRN from its own block and correlated local tracks using the DLRN of the correlated track if it has a better quality (by two qualities). This reported track will suppress reporting by a TADIL B participant as received directly via TADIL B and by a TADIL J participant as received via the forwarding CRE.

In performing R^2, a TADIL J unit will correlate its local track with any remote tracks it receives, either directly from TADIL J participants or as forwarded by the CRE. It will report uncorrelated tracks using a TN from its own block. It will report correlated tracks using the TN of the correlated track if it has a better quality (by two qualities). This reported track will suppress reporting by a TADIL J participant as received directly via TADIL J, and by a TADIL B participant as received via the forwarding CRE. If a TADIL B participant should think that it has a better quality track than that being forwarded to it based on a PPLI and so begins to report out a TADIL B track, we don't want that to be forwarded on TADIL J. The CRE, knowing the STN/DLRN association, should not transmit the TADIL B track out on the Link 16 network and should stop forwarding the PPLI out on the TADIL B network.

The forwarding rules are intended to provide a single integrated surveillance picture across both data links without duplicate tracks. However, as with a single data link, failed correlations lead to duplicate tracks and the exchange between platforms through forwarders makes correlation more difficult than with a single data link.

Platforms can operate on more than one data link at the same time but not forward. To distinguish them from data forwarders we will term them concurrent operators. The block 30/35 E-3 and Rivet Joint are such platforms. The block 30/35 E-3 and Rivet Joint operate on TADIL J and TADIL A concurrently, performing R^2 independently.



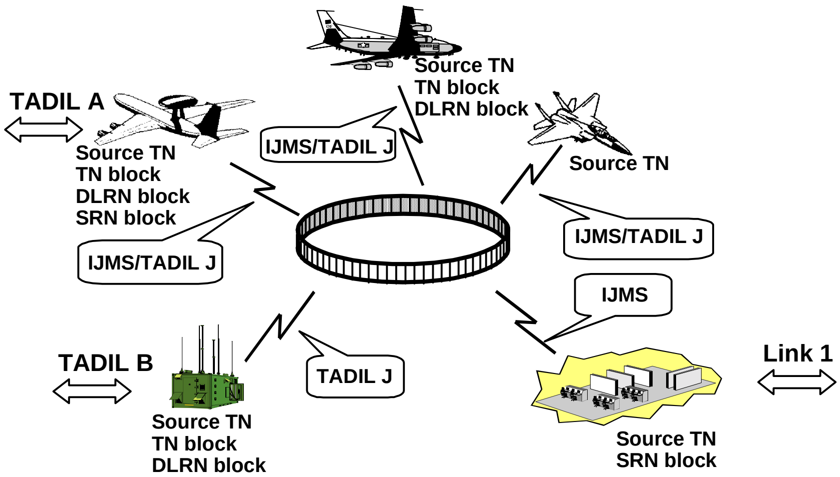
5.3-4 Track Numbering – Data Forwarding and Concurrent Operations

IJMS and TADIL J can be thought of as two separate data links utilizing the same communication media. There are no IJMS/TADIL J data forwarders[17], but the block 30/35 E-3 can be a concurrent IJMS/TADIL J participant. To operate IJMS the E-3 must be given a block of IJMS track numbers. To distinguish these from track number for other links they are termed system reference numbers (SRNs). As with TADIL J, the E-3 must have a block of DLRNs which is greater than or equal to its block of SRNs. When reporting out an IJMS track, the E-3 will draw a SRN and a DLRN for the track. Both are reported out in the IJMS track report, so a track identity message is not required to associate DLRN and SRN.

Platforms using a bilingual translating terminal can operate both IJMS and TADIL J, but none operate IJMS and TADIL J concurrently as previously defined. So while the Rivet Joint which uses a bilingual translating terminal can operate TADIL J and TADIL A concurrently, it cannot so operate TADIL J and IJMS. When transmitting, hosts using a bilingual translating terminal will send the data to the terminal only as TADIL J, and the terminal will translate that data to IJMS. It can then transmit only the IJMS data or both the TADIL J and IJMS data. However, if both IJMS and TADIL J data is sent, its the same basic data. The platform will not be operating on both IJMS and TADIL J independently, performing an independent R^2 function. This is the way the Rivet Joint transmits its data. The Rivet Joint operator can select “TADIL J” in which case the data will not be translated to IJMS, or he can select “IJMS” in which case it will be sent as both IJMS and TADIL J if there are time slots assigned for both IJMS and TADIL J transmissions. But its the same basic data. To distinguish this type of operation from concurrent operations we will term it simulcast. It will be discussed further when we explain track block and STN assignment conventions.

The above described process will lead to one entity having more than one track number (e.g., a TN, SRN and DLRN) as it is reported out on the various data links. The standards do

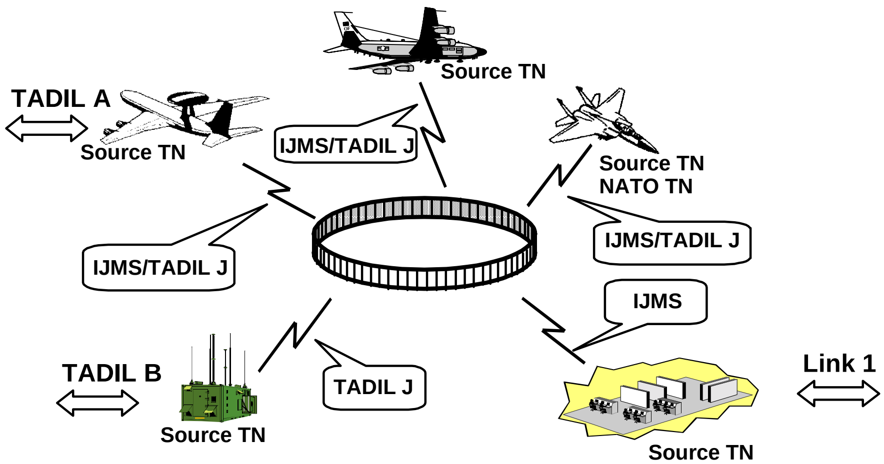
[17] The Air Force Tactical Data Link System Integration Office engineering device called the Multi-Link Translator and Display System (MTDS) often installed in a Shelterized JTIDS System (SJS) can do limited IJMS/TADIL J forwarding, but is not operational and has not be certified as such a forwarder.



5.3-5 Track Numbering – Data Forwarding and Concurrent Operations

provide a means to sort these all out, for example by using track identity messages and including both SRNs and DLRNs in the IJMS tracks, but not all platforms implement them the same[18] and even if implemented, the result can be very confusing to an operator. In our example, imagine a TADIL B participant in voice communication with the Rivet Joint. There are no common track numbers with which to reference each tracked entity. This situation is improved if the track number blocks for the various data links operated by each participant are assigned to be equivalent, and each participant operating on more than one link equates the track numbers for tracks (and other such identified data) it originates. This requirement is discussed subsequently when we explain STN and TN block assignment conventions and procedures.

[18] For example, Rivet Joint does not process the TADIL J track identifier message.



5.4-1 Track Numbering – Source Track Numbers and NATO Track Numbers

By convention, TADIL J STNs for command and control (C^2) platforms including major surveillance platforms such as Rivet Joint depend upon other tactical data links that the unit may be operating. If operating TADIL A[19], the STN should match the platform's PU number and so will lie between[20] 00001 and 00076[21]. If operating TADIL B or NATO Link 1 and not TADIL A, the STN should match the RU number and so will lie between 00100 and 00175[22]. A simple TADIL J C^2 unit can be assigned an STN between 00001 and 00076, 00100 and 00175, 00200 and 7776, and 10000 and 77776. Note that the E-3 and Rivet Joint are TADIL A capable, and that the CRC/CRE is TADIL A, TADIL B and Link 1 capable. All may be operating TADIL A and so can be assigned a STN between 00001 and 00075. The JSTARS is a simple TADIL J unit and so can also be assigned a STN between 00001 and 00075. So, for stand alone JTIDS/Link 16 training networks, the manager can simply assign STNs to his C^2 platforms starting with 00001 and proceeding up (i.e., 00002, 00003, ...). However, when working with a multi TADIL network in accordance with the standing OPTASK LINK message, the wing manager should refer to the standing OPTASK LINK message, match the multilink participants' STNs to their PU or RU numbers and, if the OPTASK LINK does not treat Link 16, assign STNs to Link 16-only C^2 participants between 00001 and 00075 which have not been assigned as PU or RU numbers.

For non-C^2 platforms, fighters in our case, the STN should lie between 00200 and 07776 or 10000 and 77776. Some platforms will receive the PPLIs and forward them as air tracks on other tactical links such as TADILs A or B. For example, in the figure the CRE might forward F-15 PPLIs as TADIL B air tracks to a community of TADIL B participants. It is desirable for the STN on Link 16 to match the track number of the air track on the other TADILs. A track number on TADIL A or TADIL B is termed a data link reference number (DLRN). DLRNs are limited to four octal digits. Therefore, fighters should normally[23] be

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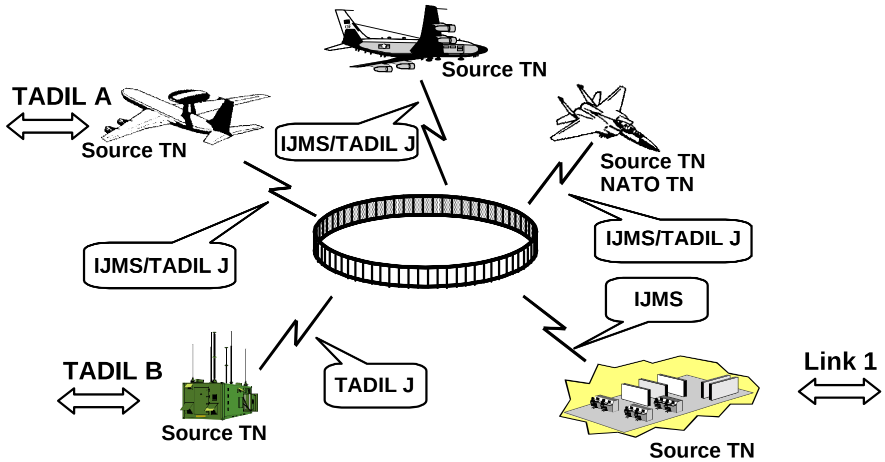
[19] The unit may also be operating TADIL B or NATO Link 1, but the TADIL A operation will determine the source TN.
[20] Inclusive of the end points.
[21] This is a constraint on PU numbers.
[22] This is desired for RU numbers, but not a hard constraint. They can lie between 001 and 076
[23] Unless it is clear that the PPLIs will not result in forwarded air tracks.

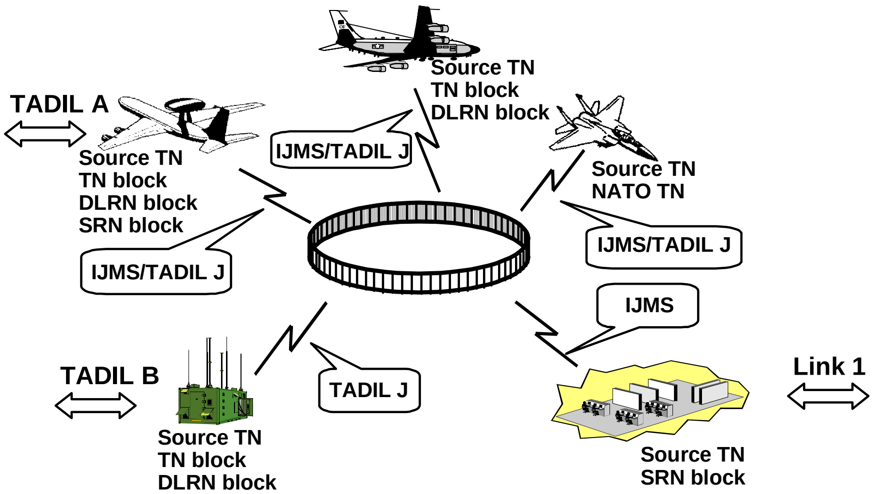


5.4-2 Track Numbering – Source Track Numbers and NATO Track Numbers

assigned STNs between 00200 and 07776. That way the leading zero can simply be dropped when the PPLI is forwarded.

Before suggesting a convention for fighter STNs, an E-3 requirement must be dealt with. The E-3 will require a block of TNs with which to report out tracks, points etc. However, some of the points, primarily reference points (e.g., CAP locations, orbit points), may have to be entered into the E-3's data base before the OPTASK LINK is published. This can be accommodated if the E-3 is given a small set of reference point TNs by convention. We will suggest a block from 00200 to 00227 octal. This represents 24 reference points. We further suggest STN assignment to fighters begin at 00230 and proceed through 00277. This provides for 40 fighters which should be more than enough for daily training. These two conventions for the E-3 reference points and the fighter STNs will require the wing manager to coordinate the reservation of from 0200 through 0277 for DLRNs in the standing OPTASK LINK with his R/SOC. DLRN assignment via the standing OPTASK LINK can begin at 0300.

When operating IJMS, the STN will be used as the source identifier for IJMS messages as well as for TADIL J messages. However, when the NADGE site receives a fighter P-message it will require a NATO track number with which to forward it on Link 1 as an air track. This will be assigned to the fighter via the OPTASK LINK and the pilot must enter it into his Class 2 JTIDS terminal so it will be transmitted in its P-message. The NADGE site will then read it from the P-message and use it to unambiguously forward the P-message as a friendly Link 1 air track. The NATO track numbers consist of two letters followed by three octal numbers. The letters are represented by 3 bit fields. The F-15 pilot can enter the NATO track number from the AFMSS or the cockpit. However, it is entered via five octal digits. Therefore, the pilot must be aware of the coding for the first two letters which is given as A=0, E=1, G=2, H=3, J=4, K=5, L=6 and M=7. NATO track numbers need not concern the wing/unit manager when acting as network manager for training networks, but he will have to be prepared to receive the NATO TNs for his platforms when operating in NATO networks involving NADGE sites and assist in their entry via the proper code.

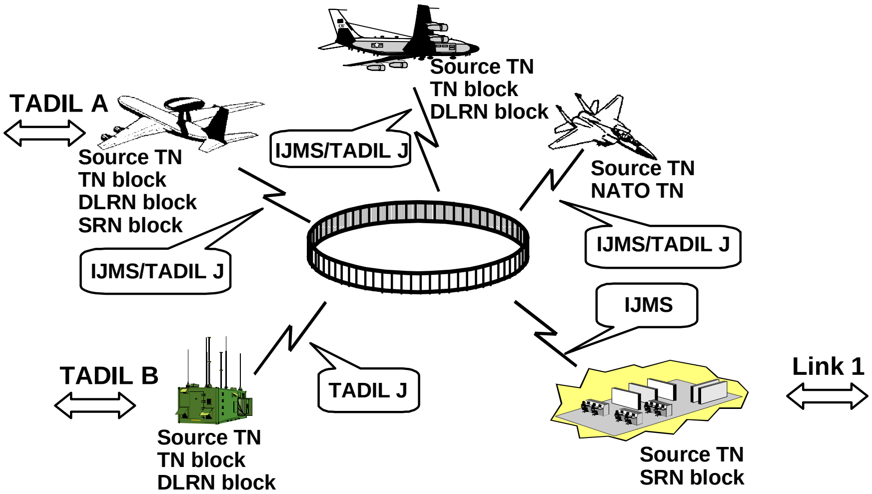


5.5 Track Numbering –Track Number Block Conventions

Surveillance platforms must be assigned blocks of TNs for reporting tracks, points and other such identified data on TADIL J. TNs can be assigned from the values between 00200 and 07776[24], 10000 and 77776 and 0A000 and ZZ777. Values below 00200 are reserved for the STNs of C^2 platforms. If the platform is operating IJMS, it must be assigned a block of IJMS track numbers with which it will identify its IJMS tracks, points etc. on the IJMS segment of the network. This includes the block 20/25 E-3. IJMS track numbers are termed system reference numbers (SRNs). SRNs consist of five octal digits and must lie between 00200 and 77776. To minimize ambiguities which may occur, it is desirable to have the same entity reported on the different data links with the same track number. Thus, in a mixed IJMS and TADIL J network, TNs should be limited to the SRN range and the SRN block assigned to the block 30/35 E-3 should match the TN block. The E-3 should match TN with SRN for tracks it originates. While the Rivet Joint can send its information on both TADIL J and IJMS, it uses a translating bilingual terminal and so can only simulcast the same information on both IJMS and TADIL J. It can not operate concurrently with independent R^2 on the two exchanges like the E-3. It will send TADIL J tracks to the terminal and the terminal will translate them into IJMS tracks using the TADIL J TN as the IJMS track SRN. So the Rivet Joint must have the same SRN block assigned as its TN block. The CRC/CRE does not operate IJMS at all, and so does not require a SRN block.

If TADIL A and/or TADIL B is involved in a multi-TADIL network, it is desirable to have the same entity reported on TADIL J/IJMS and TADIL A/TADIL B with the same track number. TADIL A/TADIL B track numbers (data link reference numbers (DLRNs)) are limited to four octal digits. Therefore, when TADIL A and/or TADIL B is involved, the TNs and SRNs should be limited to values between 00200 and 07776. Of these we have suggested that 00200 through 00277 be assigned to the E-3 for preassigned reference points and the fighters. This leaves from 00300 through 07776 representing 3903 track numbers. This should be sufficient for training networks, even multi TADIL networks[25].

[24] Inclusive of the end points
[25] However, it is becoming restrictive for large exercises.



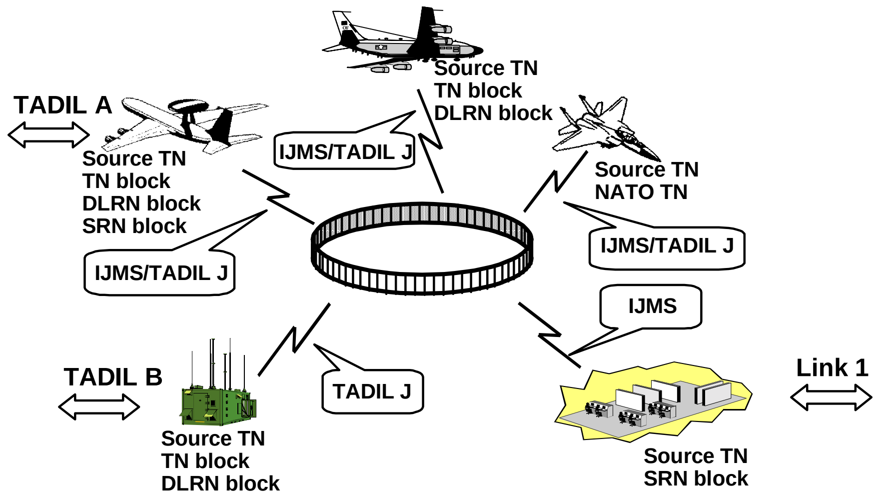
5.6-1 Track Numbering –Track Number Block Sizing

At issue is how large a TN/SRN block should be given to the C^2 platforms. In the same analysis as that which established Rivet Joint time slot requirements[26], Rivet Joint TN/SRN requirements were estimated. As for time slots, the block size requirements were estimated for a high intensity and a low intensity conflict as follows:

- Low Intensity Conflict[27] - 35 to 40 air tracks in the Rivet Joint coverage area with Rivet Joint actively amplifying approximately 70% of those tracks, supplementing coverage with its own air tracks, transmitting ground threats, etc.
- High Intensity Conflict[28] – Approximately 125 air tracks in the Rivet Joint coverage area with Rivet Joint actively amplifying approximately 60% of those tracks, supplementing coverage with its own air tracks, transmitting ground threats, etc.

For the low intensity conflict a block size of 90 should currently be allocated. With the software update due in the 4th quarter of CY 00, an increase to 100 track numbers is recommended. For the high intensity conflict the size increases to 188 track numbers (218 in the 4th quarter of CY 00). The track numbers provide for real time tracks, non real time tracks, emergency points, ground points and electronic warfare data. It considers the need to "loan" track numbers to other C^2 platforms during R^2 shifts, the fact that excess tracks may be reported with the assigned time slots with a reduced reporting rate[29], and some margin. Network managers should be aware of the number of time slots/packing limit assigned to the Rivet Joint[30] and where that places them with respect to the defined conflicts, then allocate a track number block accordingly. <u>For daily training, there should be sufficient numbers of track numbers to simplify this by giving the Rivet Joint 300 octal[31] track numbers (e.g., 00300 to 00577)</u>, a number suitable for a high intensity conflict.

[26] Reference MITRE Technical Report MTR 99B0000016 dated March 1999. The analysis was coordinated with the Rivet Joint operational community.
[27] Requires 10 s/f at packed two (5 s/f at packed four) for NPG 7 and NPG 10
[28] Requires 20 s/f at packed two (10 s/f at packed four) for NPG 7 and NPG 10
[29] But still within the data link reporting rules
[30] This is available from the connectivity matrix.
[31] $3x8^2$=192 decimal



5.6-2 Track Numbering –Track Number Block Sizing

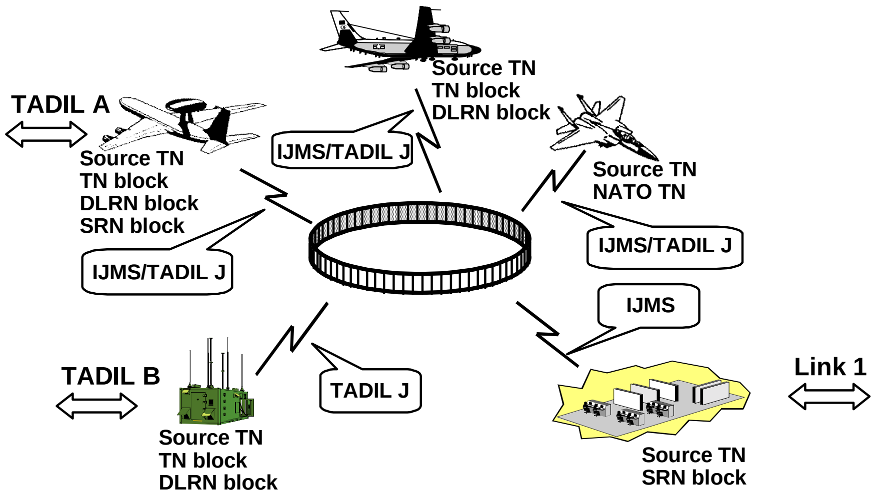
For the E-3 no such analysis has been done. However, until such an analysis is done and coordinated with the E-3 operational community, the Rivet Joint analysis can be used to develop a crude model for the E-3. As previously described, the design facility will use a simple rule of thumb based on the desired air track reporting requirement to estimate block 30/35 E-3 surveillance NPG time slot requirements. This is typically, s/f equal to the number of tracks for standard packing, ½ the number of tracks for packed two and ¼ the number of tracks for packed four where the number of tracks is the maximum number of tracks which can be reported with the nominal 12 second reporting interval. Therefore, for example, 64 s/f at packed two will support the reporting of 128 air tracks at a 12 second update interval. If the update interval is slowed to 20 seconds, the number of air tracks can increase to 213. If 30% of the assigned track numbers may be loaned out for R^2 shifts, this increases the TN/SRNs required for air tracks to 276. To this we add 20 ground points and 20 electronic warfare reports[32] reaching 316, then 25% margin for a total of 395 track numbers. Dividing by the 128 air tracks the result is a factor of about 3. So a simple TN/SRN assignment rule of thumb for block 30/35 E-3 is to assign a track number block which is at least 3 times the nominal track reporting requirement. This is a reasonable factor for the block 20/25 E-3 as well, although the conversion of nominal air track requirements to s/f is different[33]. Network managers should be aware of the number of time slots and for the block 30/35 packing limits assigned to the E-3, and where that places them with respect to the nominal air track reporting capability, then allocate a track number block accordingly (i.e., 3 times that value). For daily training 128 nominal air tracks is quite a lot[34]. So <u>for daily training the network manager can simplify track number block assignment by giving the E-3 700 octal[35] track numbers (e.g., 00600-01477)</u> which is more than enough to support 128 nominal tracks. <u>This track block sizing rule could also be applied to the CRC/CRE.</u>

[32] Note that we include no maritime surface tracks so the TN block might be low if the E-3 is performing tactical support to maritime operations (TASMO).

[33] Recall, we use the 4/3 rule where 4/3x the nominal air tracks is assigned to the IJMS transmissions.

[34] For the block 20/25 E-3, 128 nominal tracks will require 176 s/f using the 4/3 rule.

[35] $7 \times 8^2 = 448$ decimal.

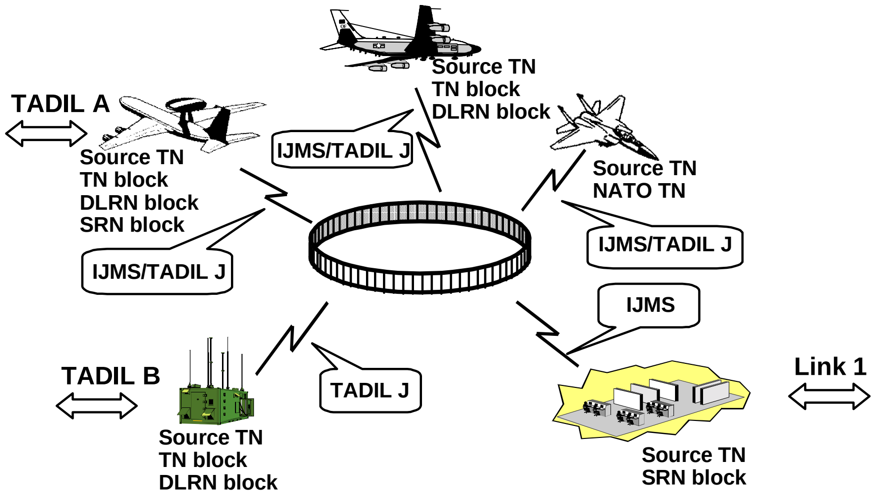


5.7-1 Track Numbering –STN and TN Block Assignment Procedures Summary

The background and assignment conventions discussed in this section are now summarized in a set of STN and TN block assignment procedures. The procedures depend on whether or not the wing manager is operating a stand alone JTIDS/Link 16 network or is operating as a part of a multi TADIL network which is using the standing OPTASK LINK of his associated R/SOC. We will discuss the two separately.

Stand Alone JTIDS/Link 16 Network. The manager will assign STNs to his C^2/surveillance platforms as five octal digits starting with 00001 and assigning sequentially (i.e., 00001, 00002, ...). The STN less the first two digits[36] will be the PU number for the E-3 (e.g., 001). Similarly, the STN less the first two digits would be the PU number for the Rivet Joint if it were operating TADIL A and the RU number for a CRC/CRE if it were operating TADIL B. If the E-3 and Rivet Joint are operating IJMS, the IJMS participant identifier is their STN. The manager will assign STNs to his fighters as five octal digits starting with 00230 and assigning sequentially through 00277. He will reserve TNs of 00200 through 00227 for use by the E-3 in entering preassigned reference points into their data base. The E-3 will also use the same block for preassigned IJMS reference points and the same block less the first digit for preassigned TADIL A reference points. The manager will assign TN blocks to his C^2/surveillance platforms as five octal digits starting with 00300 and assigning sequentially through 07776. He will assign a 700 octal block to each E-3 and CRC/CRE, and a 300 octal block to each Rivet Joint. For the block 30/35 E-3, if the network is a mixed TADIL J/IJMS network, the E-3 will assign an SRN block equal to its TN block and a DLRN block equal to its TN block less the first digit. For the block 20/25 E-3 a TN block is not required. It will enter a SRN block equal to the assigned TN block and a DLRN block equal to the TN block less the first digit. For the Rivet Joint, if the network is a mixed TADIL J/IJMS network, it will use a SRN block equal to its TN block. Operator entry of a SRN block for Rivet Joint is unnecessary.

[36] PU/RU numbers are three octal digits since they be less than 200 octal.



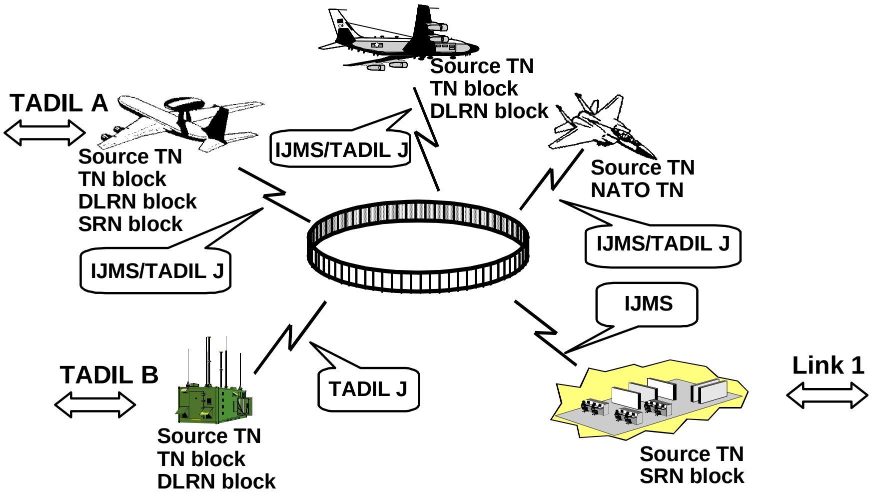
5.7-2 Track Numbering –STN and TN Block Assignment Procedures Summary

A JTIDS/Link 16 Network as Part of a Multi TADIL Network. We assume that the ICO at the R/SOC will manage TADILs A and B, and that the wing manager will manage JTIDS/Link 16. The wing manager will coordinate with his R/SOC to reserve DLRNs 0200 through 0277 for use by the E-3 for preassigned reference points (block 0200-0227) and by fighters for their STNs (block 0230-0277). This should be noted in the standing OPTASK LINK which will then begin DLRN block assignments with 0300. He will also coordinate with the R/SOC to ensure that DLRN blocks of at least 700 octal are assigned to the E-3 and CRC/CRE and of at least 300 octal are assigned to Rivet Joint in the standing OPTASK LINK. The wing manager will obtain the standing OPTASK LINK.

All C^2/surveillance platforms covered in the standing OPTASK LINK will have PU/RU numbers assigned. The manager will assign STNs equal to their PU/RU numbers but with two zero leading digits added. The standing OPTASK LINK may not include all C^2/surveillance platforms (e.g., may not include JSTARS since it has no TADIL A or B capability). The manager will assign a STN to such C^2/surveillance platforms. He will look for the lowest PU/RU numbers not assigned in the standing OPTASK LINK and assign them to the unassigned C^2/surveillance platforms adding two leading zero digits. He will assign STNs to fighters as five octal digits starting with 00230 and proceeding through 00277.

For all C^2/surveillance platforms covered in the standing OPTASK LINK, the manager will assign a TN block equal to their assigned DLRN block plus an initial zero digit. For C^2/surveillance platforms not covered in the standing OPTASK LINK (e.g., JSTARS), a TN block will be assigned. The manager will look for the lowest DLRN block of suitable size[37] which is not used in the standing OPTASK LINK and assign it with the addition of a zero leading digit as the TN block. If the manager finds that the standing OPTASK LINK is using all available DLRNs, he should coordinate with the R/SOC to have the C^2/surveillance platforms which are not included in the standing OPTASK LINK added and given suitable DLRN blocks, even if they do not operate TADILs A or B, so that STNs which equate to DLRNs can be assigned to them. If this is done, a PU/RU number should also be reserved.

[37] An analysis of JSTARS timeslot assignment and TN assignment requirements has not yet been done.



5.7-3 Track Numbering –STN and TN Block Assignment Procedures Summary

For the block 30/35 E-3, if the network is a mixed TADIL J/IJMS network, the E-3 will assign an SRN block equal to its TN block. For the block 20/25 E-3 a TN block is not required. It will enter a SRN block equal to the assigned TN block. For the Rivet Joint, if the network is a mixed TADIL J/IJMS network, it will use a SRN block equal to its TN block. Operator entry of a SRN block for Rivet Joint is unnecessary.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

5.8-1 Track Numbering – The OPTASK LINK

The STN and TN block is distributed via the JUDATA SETID of the OPTASK LINK as shown in the figure. STN is provided in the third field. In the example we have assigned 00001 to the E-3, 00002 to the CRE with voice call sign Blue Boy, 00003 to the CRE with voice call sign Red Top, 00004 to the Rivet Joint, 00230-00233 to the four-ship Hogger flight and 00234-00237 to the four-ship Eagle flight.

The TN block is provided to the surveillance platforms in the last field. In the example we have assigned 00300 to 01177 to the E-3 (700 octal TNs in accordance with our suggested block size[38]), 01200 to 02077 to the CRE with voice call sign Blue Boy, 02100 to 02777 to the CRE with voice call sign Red Top and 03000 to 03277 to the Rivet Joint (300 octal in accordance with our suggested block size[39]).

The SRN blocks are intended to be sent in an IJMS portion of the OPTASK LINK message. This portion starts with a SETID of LNKIJMS/IJMS//. The SETID for the blocks is IJMSDATA similar to JUDATA. Field 2 is the STN and field 4 is the SRN block. In this example, equating SRN block with TN block we would have

IJMSDATA/964 AWACS:E-3:MAGIC:00001/-/-/00300-01177//
IJMSDATA/97 IS:RC-135:VACUUM:00004/-/-/03000-03277//

This is also where we would assign STN and the SRN block to a block 20/25 E-3.

However, for daily training networks, the block 20/25 E-3 will virtually always be operating in a mixed IJMS and TADIL J network, so there will always be a Link 16 portion of the OPTASK LINK message. This suggests a way to simplify tasking the block 20/25 E-3 and the block 30/35 E-3 when operating in a mixed IJMS/TADIL J network. We can

[38] This is 448 track numbers in decimal.
[39] This is 192 track numbers in decimal.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

5.8-2 Track Numbering – The OPTASK LINK

adopt a convention in which the block 30/35 always matches its SRN block to the TN block assigned via the Link 16 portion of the OPTASK LINK, and the block 20/25 E-3 always takes its SRN block as matching the TN block it is assigned in the Link 16 portion of the OPTASK LINK. Furthermore, for stand alone JTIDS/Link 16 training networks which do not involve TADILs A or B, we can have the E-3, both block 20/25 and block 30/35, always enter their required DLRN block as matching their assigned TN block, except with the lead digit dropped. Then we can assign all track blocks via the Link 16 portion of the OPTASK LINK. This is what we recommend. The block 20/25 E-3 would then be assigned its SRN and required DLRN block with the JUDATA SETID which would look as follows:

JUDATA/964 AWACS:E-3:MAGIC/00001/E3I.1/-/-/-/-/00300-01177//

where the I following E3 in the participant identifier denotes Class 1 terminal equipped (i.e., the block 20/25 E-3).

The convention to be used should be given in the OPTASK LINK as a GENTEXT SETID. We suggest the following:

GENTEXT/FOR MIXED IJMS AND TADIL J OPERATIONS, E-3S SHOULD MATCH THEIR SRN BLOCK AND THEIR REQUIRED TADIL A DLRN BLOCK TO THEIR ASSIGNED TN BLOCK. AN SRN BLOCK HAS NOT BEEN ASSIGNED VIA AN IJMS PORTION OF THE OPTASK LINK.//

The IJMS portion of the OPTASK LINK message is also where one would expect to find the fighter NATO track number assigned. However, there is no SETID which does this. It would have to be done via the GENTEXT SETID. Fighters should look for it in either the IJMS or Link 16 portions of the OPTASK LINK in a GENTEXT SETID.

In garrison responsibilities in support of operations managed by personnel other than at wing:

2. If operating in a NATO network involving NADGE sites, wing/unit managers for fighters should be prepared to receive NATO TNs for their fighters and to help make their entry using the appropriate coding for the first two letters. Look for the NATO TNs as part of the GENTEXT SETID of the IJMS or LINKXVI section of the OPTASK LINK, or by telecon. Reference: para 5.4-2

Network manager responsibilities for daily training network operations:

For Stand Alone JTIDS/Link 16 Networks

6a. Reserve TNs 00200 through 00227 for preassigned E-3 reference points, and be sure the 552 ACW is aware of this convention.Reference: para 5.7.2

7a. Assign source track numbers (STNs) to all JTIDS/Link 16 participants as five octal digits. For daily training networks assign STNs to C^2 units between 00001 and 00076 starting with 00001 and to fighters between 00230 and 00277 starting with 00230.Reference: para5.7-1

8a. Assign TADIL J track number (TN) blocks to all surveillance platforms as five octal digits between 00300 and 07776 starting with 00300. For daily training networks for the E-3 assign a block of 700 octal (448 decimal) and for the Rivet Joint a block of 300 octal (192 decimal). The E-3 guidance may be applied to the CRE/CRC.Reference: para 5.7-1

9a. For daily training networks which mix IJMS and TADIL J, the E-3 should match its SRN block to its assigned TN block and its DLRN block equal to its TN block less the leading zero. The Rivet Joint requires no SRN block per se, but will use a SRN block which is equal to its TN block when it simulcasts on both IJMS and TADIL J. With this convention, no distribution of SRNs via OPTASK LINK will be required. Reference: para 5.7-1

5.9-1 Track Numbering – Wing/Unit Manager Checklist

The wing/unit manger checklist begun in the preceding network management section is extended here. It is further extended with each subsequent section and is given in its entirety in the last network management section. This part of the checklist applies to stand alone JTIDS/Link 16 network operations.

For JTIDS/Link 16 Networks Which are a Part of a Multi TADIL Network

6b. Coordinate with the R/SOC to reserve DLRNs 0200 through 0227 for preassigned E-3 reference points, and be sure the 552 ACW is aware of this convention, and to reserve DLRNs 0230-0277 for fighter STNs. Also ensure that the DLRN blocks assigned to the E-3 and CRC/CRE in the standing OPTASK LINK are at least 700 octal in size and that the DLRN block assigned to the Rivet Joint is at least 300 octal in size. If the standing OPTASK LINK uses all available DLRNs on TADIL A and B participants (i.e., none available for JTIDS/Link 16-only C^2/surveillance units), coordinate with the R/SOC to reserve suitable DLRN blocks and PU/RU numbers for the JTIDS/Link 16-only C^2/surveillance units. Reference: para 5.7-2

7b. Assign source track numbers (STNs) to all JTIDS/Link 16-only C^2/surveillance units covered in the standing OPTASK LINK equal to their PU/RU number plus two leading zero digits. JTIDS/Link 16-only C^2/surveillance units not covered should be given a STN equal to the lowest unassigned PU/RU number plus two zero leading digits. Assign STNs to all fighters starting with 00230 and sequencing through 00277. Reference: para 5.7-2

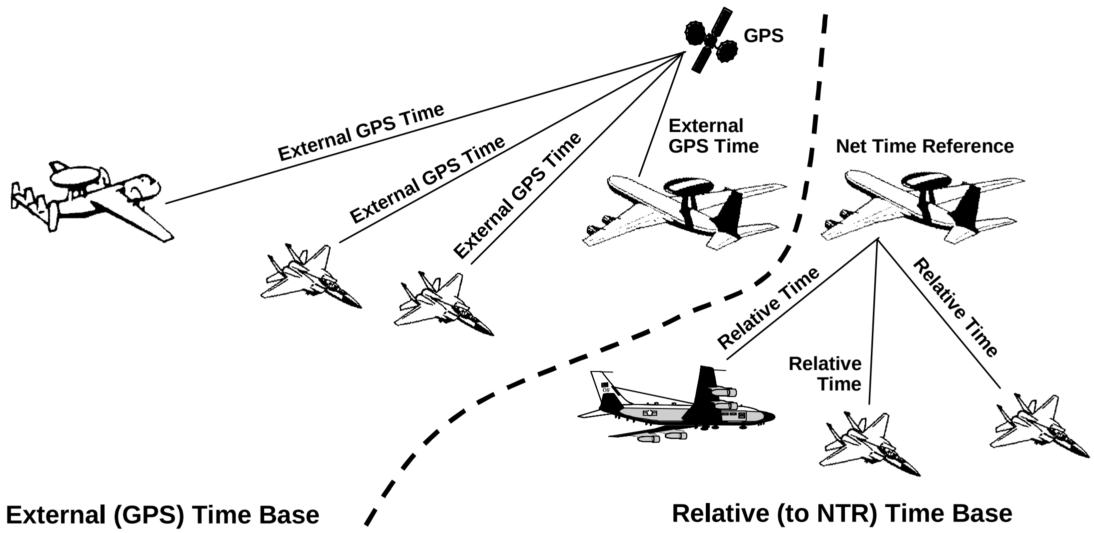
8b. For all JTIDS/Link 16-only C^2/surveillance units covered in the standing OPTASK LINK, assign TADIL J track number (TN) blocks equal to their assigned DLRN block plus a zero leading digit. JTIDS/Link 16-only C^2/surveillance units not covered should be given a TN block equal to the lowest unassigned DLRN block of suitable size plus one zero leading digit.Reference: para 5.7-2

9b. For daily training networks which mix IJMS and TADIL J, the E-3 should match its SRN block to its assigned TN block. The Rivet Joint requires no SRN block per se, but will use a SRN Reference: para 5.7-3

5.9-2 Track Numbering – Wing/Unit Manager Checklist

This part of the checklist applies to JTIDS/Link 16 network operations as a part of a larger multi TADIL operation. The checklist summarizes the recommendations given in each section. If the wing/unit manager finds them inappropriate due to circumstances which are at odds with the associated assumptions, it is hoped that the background given in each section is sufficient for him to adapt to the situation.

6.0 Synchronization



6.1 Synchronization – Time Bases

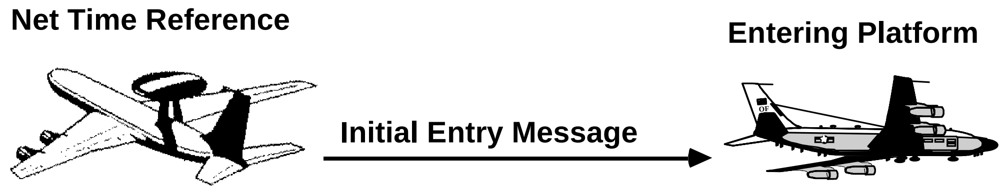
Every JTIDS/MIDS terminal contains an electronic clock. However, the clocks do not provide the terminals with a common understanding of network time (i.e., time slot boundaries) of sufficient accuracy to operate a JTIDS/Link 16 network. There are two fundamental approaches to establishing a sufficiently accurate understanding of network time. One approach is to use a relative time base. With a relative time base, one, and only one, participant is designated **the** net time reference (NTR). The NTR's clock is then considered perfect network time. To establish a common understanding of network time, all of the other network participants correct their clocks so as to become synchronized with the NTR's clock. The NTR's time may be inaccurate in absolute terms, but a common understanding of network time is all that is required, not a common understanding of absolute time.

The second approach is to use a time base established by some external time reference. The external time reference being used for Link 16 is GPS time[1]. Network time is considered to be GPS time and network participants[2] will synchronize to the external time reference (ETR) by interfacing with a GPS receiver. In this way the participants achieve a good understanding of network time and absolute time. They're the one and the same.

To date, Link 16 networks have primarily used a relative time base, so that approach will be discussed first. However, there are significant advantages to operating with a GPS time base, so that approach is discussed as well.

[1] Throughout this document, the term "GPS time" actually refers to the UTC time provided by GPS. In GPS nomenclature, GPS time actually differs from UTC time by a certain number of leap seconds. JTIDS really uses UTC time not GPS time, but it is convenient to refer to it as "GPS time" in the present context.

[2] Not all network participants are required to synch with the ETR, but this will be covered subsequently, when ETR is covered in detail.



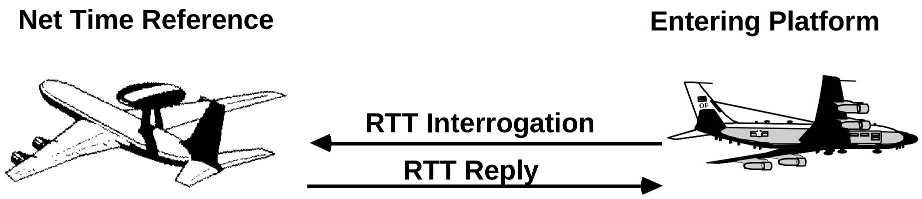
6.2 Synchronization – Coarse Synch

To begin the network synchronization process, the operator in the net time reference (NTR) will initialize his/her[3] terminal as NTR, set his terminal's clock to the desired network time[4], and then send a start net entry command to the terminal. Since the terminal is NTR it will take the time associated with its clock as network time, declare itself synchronized with network time[5] and begin to operate on the network (i.e., transmitting and receiving). One message that it will begin to transmit is an initial entry message. The initial entry message is sent once per 12 second frame on net 0 in a time slot reserved for net entry, and we will call it the initial entry slot[6].

As previously mentioned, the frequency hopping pattern is a function of cryptokey and net number. However, using the same encryption slot after slot, day in and day out would increase the vulnerability of the system. Therefore, the terminal changes the encryption used for the hopping pattern and message encryption from slot to slot for each 24 hour period and we change the cryptokey each 24 hours, so that the same encryption/hopping pattern is never repeated. The terminal makes use of this situation for synchronization.

To synchronize with the network, the operator of the entering terminal will set his clock as best he can to the desired network time, provide an estimate of the uncertainty in his clock after being set[7], and send a start net entry command to the terminal. The terminal will then set up to receive the next initial entry message it expects to be transmitted after one time uncertainty has gone by. By "set up" we mean begin to look for the frequency hopping pattern and initial entry message associated with that slot. As long as the terminal clock error is less than the specified uncertainty, the initial net entry message being sought will occur in the future. The terminal need only wait patiently. When it receives the message the terminal will measure the time of arrival with its clock. It will know the time the message was transmitted in network time[8]. It can then calculate the error between its clock and network time to within the propagation delay between the NTR and itself, correct its clock and declare "coarse synch". The terminal now knows network time well enough to receive messages, at least from the NTR, and can advance to the next step in the synchronization process.

[3] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.
[4] Normally Zulu time
[5] Termed fine synch, as will be discussed subsequently.
[6] This is the set A, index 0, recurrence rate number (RRN) 6 time slot, for those familiar with the time slot labeling convention. Even if assigned for another purpose, the terminal will not use the initial entry slot for anything but initial entry.
[7] In some cases time uncertainty is automatically set. This will be discussed further subsequently.
[8] Any platform using the same cryptokey and net number would have transmitted at the same time.



6.3-1 Synchronization – Fine Synch

Once in coarse synch the entering terminal will begin to transmit round trip timing (RTT) interrogation messages to the NTR. RTTs are special messages. The interrogation message is received by the NTR terminal, its time of arrival in network time is measured, and the terminal issues a RTT reply in the same time slot. The reply contains the measured interrogation's time of arrival, and its transmission starts a fixed amount of time after the start of the time slot in network time. The entering terminal will receive the RTT reply and measure its time of arrival with reference to its clock. Knowing the time the interrogation was received by the NTR in network time (T_I), the time of reply transmission in network time (T_D), and the time of arrival of the reply in its clock time (T_R), the terminal can calculate the error between its clock time and the NTR's network time quite precisely[9]. It uses the error calculation to begin to build a mathematical model of the error between its clock and network time, including its frequency error. It continues to issue RTT interrogations, and for each reply it makes a new error calculation and improves its clock error model (i.e., reducing the clock bias and frequency errors). When its clock error model is good enough that the terminal could accurately predict time up to 15 minutes, without additional RTT updates, it declares itself to be in "fine synch". RTTs then continue to be automatically exchanged periodically to maintain an accurate clock model (i.e., maintain fine synch).

Actually, even after it has achieved fine synch the terminal will continue to improve its clock model. How good the model is depends upon how stable the clock is. When a terminal is first turned on the clock will be least stable. It takes time for the clock to "warm up". So when a terminal is first turned on, the clock error model is sort of "chasing" the clock frequency error which is varying non-linearly as the clock warms up. Once the clock is warmed up, the clock's frequency error will change much more slowly with time, so the terminal will obtain a stable model[10] of the clock's error with a very small residual error. Because of this warm up time, the time a terminal can stay in synchronization with a network when it is no longer within line of sight or range of any network participant (and therefore no longer receiving RTT sync updates) depends upon how long the terminal has been on. The

[9] $E=(T_I - T_R + T_D)/2$

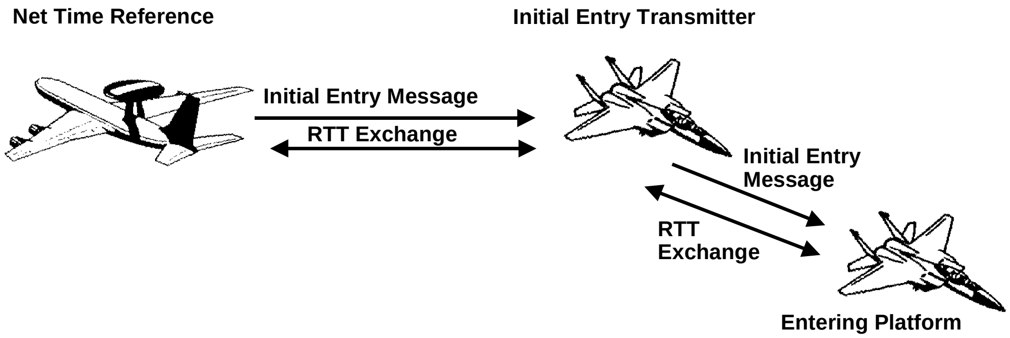
[10] The model once obtained will change very slowly.

Time the terminal has been on, warming up (minutes)	Time to remain in synchronization (hours)
15 including time to fine synch	2.0
25 including time to fine synch	2.5
35 including time to fine synch	3.5
45 including time to fine synch	4.0
55 including time to fine synch	5.0

6.3-2 Synchronization – Fine Synch

specification for both the MIDS and JTIDS terminal is given in the table above. The terminal need not have been in synch for the specified time, but it must have been on for that time and during that time acquired a good clock error model. For the Class 2 and MIDS terminal, a good clock error model can be established in about 5 minutes[11].

[11] For example, an F-15 could be in the network for an hour, perform a master reset to change its initialization data set, reenter the network and after 5 minutes or so fly out of line of sight of any network participant, and it would maintain synch for about 5 hours.



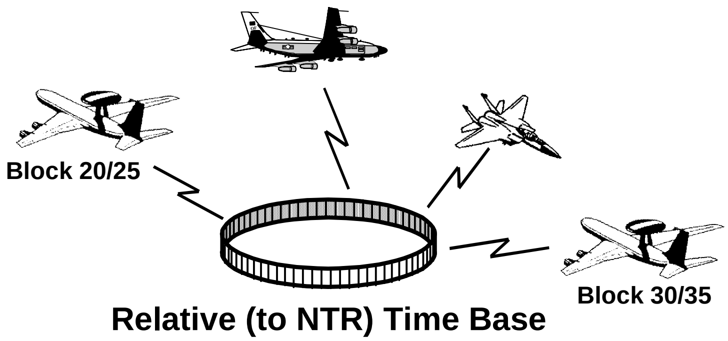
6.4 Synchronization – Initial Entry Transmitter

The process thus far described is all right if the entering platform is within line of sight of the NTR, but this may not always be the case. Any and all terminals can be initialized to be an initial entry message transmitter. Once in fine synch the terminal will begin to transmit the initial entry message itself. It will transmit it in the same slot as the NTR, but only once every 24 seconds rather than once per frame as the NTR does. In the figure we show one F-15 within line of sight of the NTR (at the top) and another which is not. The one that is will enter as described via the NTR. We will initialize him to be an initial entry transmitter. The second F-15 will set up to look for the initial entry message and will receive that being transmitted from the first F-15 since he doesn't see the NTR. Remember, its fine for many participants to be transmitting in the same slot, and the entering terminal will simply enter on the closest one. However, in the example, the first F-15 may not transmit in the slot the second F-15 looks in since it only transmits in every other net entry slot. This is fine since when the entering terminal fails to enter (i.e., waits an uncertainty past the expected entry slot) it will set up for the next available initial entry slot and try again. But can't a terminal become synchronized with the empty slot and never get in? No, the initial entry transmitter randomly selects one of the two initial entry slots available every 24 seconds in which to transmit its initial entry message so such synchronized failure can't occur. However, <u>when entering on an initial entry transmitter rather than the NTR the entering platform may take longer than normal to achieve coarse synch because of some failures</u>.

The terminals maintain an estimate of their time accuracy (i.e., an estimate of their residual error). This is published in their PPLI as time quality. The highest time quality is 15 and only the NTR will have that quality[12]. Once in coarse synch the terminal will try to obtain fine synch. It will begin to receive PPLIs and maintain a table of those terminals it receives from directly which have the highest time quality. It will then interrogate the terminal in its table which has the highest time quality, not necessarily the NTR. If it fails to get a reply, it will RTT to the next best source in its table, etc. In this way the terminals all automatically maintain the best time quality possible given the participants they can reach with RTT exchanges[13].

Most if not all network participants are initialized as initial entry transmitters. It is a part of the network design.

[12] At least only the NTR in a relative time based network.
[13] At least they do when they are in the primary user mode which is normally used. Other user modes are discussed subsequently in this section and in the navigation section.



6.5-1 Synchronization – Individual Terminal and Platform Implementations

The Class 1, Class 2 and MIDS terminals, and individual platforms all handle synchronization a bit differently. We'll describe each beginning with the F-15 with either the Class 2 terminal or the MIDS/FDL.

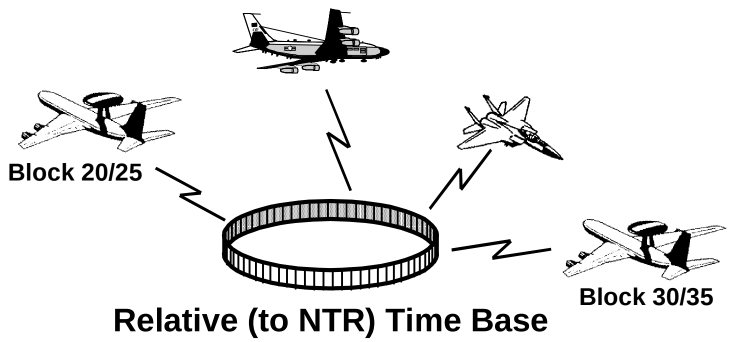
The F-15 with a Class 2 or FDL terminal will be discussed first. Suppose a flight of F-15s wishes to operate an autonomous Link 16 network solely for interfighter exchanges. One F-15, perhaps the flight leader, will be designated NTR. This can be done via the AFMSS with the "NTR" initialization parameter placed in the associated initialization data set on the F-15's data transfer module. However, this is not recommended. It has led to multiple NTRs[14] and associated network problems which will be described subsequently. We recommend that NTR be deselected at the AFMSS (i.e., in all initialization data sets on the data transfer module (DTM)) and that NTR selection be made via the cockpit on the OWN DATA page of the multipurpose color display (MPCD) menus when the NTR initiates the network. This minimizes the risk of multiple NTRs.

The pilot of the F-15 which is NTR will begin to initiate the network by checking his terminal's clock on the MENU page. If it is close to the desired network time, i.e., within a few seconds, he need not reset the clock. If it is not close, he must go to the TIME/DATE page, enter a future time and send it to the terminal (press ENTER TIME) when the time occurs. He then selects ENTER NET and his terminal will shortly report fine synch ("FINE"). The terminal, being NTR, will begin to transmit the initial entry message and the other F-15s can now enter the network on it.

The pilot of each of the other F-15s will begin his network entry process by checking his terminal's clock. If it is not close to the desired network time, i.e., within a few seconds, he must reset his clock. Otherwise, he can simply select ENTER NET.

The Class 2 and FDL terminals have a default time uncertainty which is 6 seconds times the number of days since the terminal was synchronized with a network. This default value is used for net entry unless the pilot enters time (i.e., sets his clock). If the pilot sets his clock, the F-15 overwrites the default uncertainty with one minute. A six second uncertainty is short. Remember, with this uncertainty, if the clock time is more than 6 seconds ahead of the network time, the F-15 may never achieve coarse synch (i.e., the slot

[14] For example, a pilot may have a DTM upon which NTR has previously been designated without realizing it and another pilot may be selected as NTR and enter his selection via the cockpit.



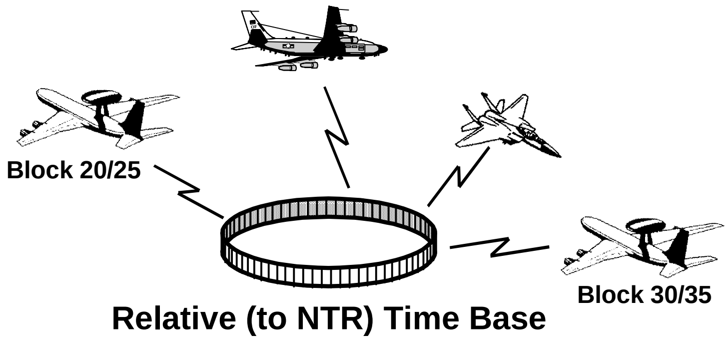
6.5-2 Synchronization – Individual Terminal and Platform Implementations

selected for entry may have already gone by). So when first entering a network, it is advisable for the pilot to enter time and use a 1 minute uncertainty. Of course, this will lengthen the time to enter since the terminal will set up for an initial entry slot at least one minute in the future. However, it will increase the likelihood of entry. If an F-15 drops out of a network, and wishes to immediately reenter the same network (e.g., if he does a master reset to change an initialization load), that is the perfect situation for the pilot to **not** enter time and let the terminal use the default uncertainty of 6 seconds. The pilot knows his corrected clock time is good and the low uncertainty will speed the reentry process. Once the terminal has started to enter the network the pilot will see status change from “PENDING” to “COARSE”. The fine synch process will be initiated and within 30 seconds or so he should see his status change to “FINE”.

The Rivet Joint permits the operator to designate his terminal as NTR on the main JTIDS menu prior to terminal initialization. It does not provide the operator with the ability to set his clock[15] or enter time uncertainty. When the operator is ready to enter the network, he simply commands start net entry (i.e., with “TJGO” command) via the main JTIDS menu. The host processor will automatically precede the actual command to the terminal by setting the terminal’s clock to GPS based Zulu time and overwriting the default time uncertainty with 1 minute. Thus, the Rivet Joint will normally take about one minute for net entry and can only operate in networks operating within a minute of GPS based Zulu time. This will be discussed further subsequently.

The block 30/35 E-3 communication technician can designate his terminal as NTR via the NORMAL USER DATA page of the control monitor set (CMS). He will enter the network via the TIME OF DAY page. He will check terminal clock time, set it if required (i.e., more than a few seconds from desired network time) using INIT TIME OF DAY and specify time uncertainty (unless terminal default is acceptable) using TIME OF DAY ERROR prior to pushing START NET ENTRY. The block 20/25 has used a 30 second uncertainty with some success and it can also be used by the block 30/35 E-3 with the understanding that if the aircraft does not achieve coarse synch, attempting again with a larger uncertainty (e.g., 1 minute) can be tried.

[15] This will be changed, and the entry of time permitted with updated software due in late CY 99.



6.5-3 Synchronization – Individual Terminal and Platform Implementations

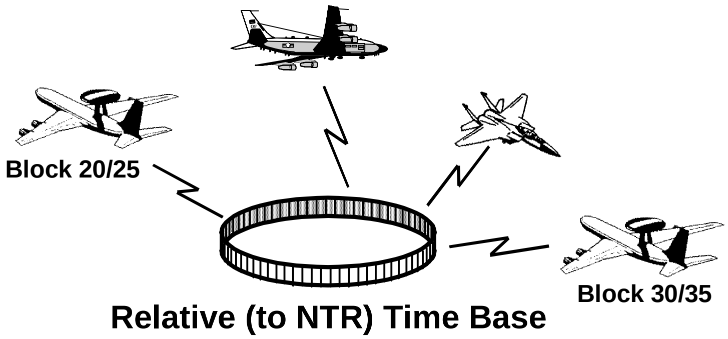
The block 20/25 E-3 uses the JTIDS Class 1 terminal and its radio set control (RSC). Selection of NTR is made by designating itself as MASTER. However, unlike the Class 2 terminal, this does not cause the Class 1 terminal to transmit an initial entry message. That requires the communication technician to set the first digit of TERM TEST METHOD to "1". This is also how he will designate himself an initial entry transmitter if he is not the NTR.

If NTR, the communication technician will enter the network time[16]. This will automatically result in a start net entry command being sent to the terminal. After start net entry, the block 20/25 terminal will declare fine synch and begin to transmit a IJMS net entry message termed the net entry aid (NEA). It will use the initial entry slot, but not necessarily on net 0. It will transmit it on the MAIN NET, another Class 1 terminal parameter entry. The MAIN NET is the net on which the terminal will transmit all of its messages. Only if the MAIN NET is 0 can the Class 2 and MIDS terminals enter on the Class 1 terminal's NEA message. All Class 2 and MIDS terminals can so enter (achieve coarse synch) on the Class 1's IJMS NEA message. Class 2 terminals will look in the initial entry slot on net 0 for the initial entry message. Class 1 terminals must be instructed as to which slot to look in. This is entered by the communication technician as "A 00000 06", the NET ENTRY SLOT.

If not NTR, the communication technician will enter his estimate of network time and time uncertainty which will result in a start net entry command being sent to the terminal. The Class 1 terminal will only enter on an IJMS NEA message. Therefore, to support entry of Class 1 terminals, Class 2 and MIDS terminals are equipped to alternate the transmission of the IJMS NEA message and the TADIL J initial entry message in the initial entry slot[17]. This capability must be selected by an initialization parameter which is set during the network design process. It can be selected for the block 30/35 E-3, Rivet Joint and F-15, and

[16] The Class 1 terminal clock must always be set in the block 20/25 E-3 and the comm tech should also enter a usable time uncertainty such as "5" for 30 seconds, even though it is ignored when MASTER is selected.

[17] A Class 2 or MIDS NTR sends entry messages every 12 seconds. When so initialized to work with IJMS platforms, it sends TADIL J initial entry messages once every 24 secs and IJMS NEA messages once every 24 seconds, alternating with TADIL J initial entry messages. A Class 2 or MIDS non-NTR which is initialized as an initial entry transmitter will send entry messages an average of once every 24 secs, randomly selecting one of the two initial entry slots in every 24 second period. When so initialized to work with IJMS platforms, it alternates TADIL J initial entry and IJMS NEA messages in the selected slots, which means that the average interval between TADIL J initial entry or IJMS NEA messages is really 48 seconds.



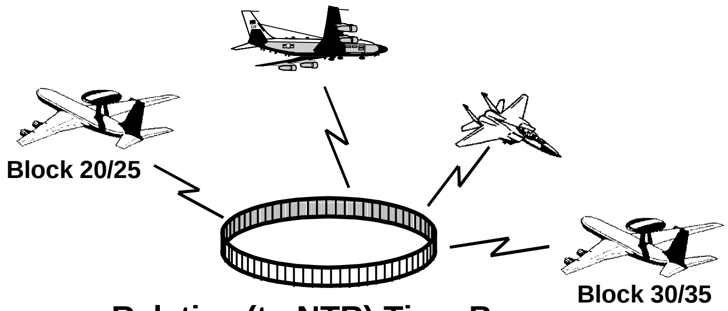
6.5-4 Synchronization – Individual Terminal and Platform Implementations

normally is for mixed IJMS/TADIL J networks. It is not easily accessible by the CRC/CRE which implemented only TADIL J. This has caused problems when it was desired that the CRC/CRE be NTR and block 20/25 E-3s were involved in the network. The block 20/25 E-3s could only enter on the Rivet Joint or an F-15 after they had entered on the CRC/CRE, and could not enter the network at all until one of those platforms was present.

If entering on a Class 2 terminal, the Class 1 terminal will set up for the next initial entry slot after the time uncertainty. It may select a TADIL J initial entry message slot. If it does it will fail, recycle and set up once more for the next initial entry slot. Eventually it will select an slot containing an IJMS NEA message, but this will generally take longer than if it were entering on another Class 1 terminal, and the time uncertainty entered for the block 20/25 E-3 is critical. Time uncertainty is entered as a multiple of 6 seconds. If an even number is entered so that the uncertainty is a multiple of 12 seconds, its tries can become synchronized with the TADIL J initial entry message transmissions and it will never achieve coarse synch on the alternating IJMS NEA messages. So the block 20/25 E-3 should enter a time uncertainty number which is an odd multiple of 6 seconds. A value of 5 for 30 seconds uncertainty is suggested. However, if the E-3 has trouble entering, one thing to try is to lengthen the time uncertainty, e.g., to 66 seconds[18].

Once in coarse synch, the participants must RTT to acquire and maintain fine synch. For Class 2 and MIDS terminals, RTTs are normally exchanged in network participation groups (NPGs) 2 or 3 based on the time quality as received in PPLIs. The difference between the two NPGs isn't important to the operators. However, in networks which are strained for capacity, such as those under peacetime electromagnetic compatibility constraints, and which assign PPLIs with the dedicated access mode, RTT NPGs can be forgone and the Class 2 terminals will preempt an occasional PPLI time slot in which to exchange RTTs. This is of interest to the operators because it effects the PPLI exchange rate. For example, PPLIs are normally transmitted by F-15s in this circumstance every 3 seconds. Occasionally, a PPLI will be preempted by an air platform and system status message providing fuel remaining, armaments remaining, etc. This currently occurs every 3.2 minutes, but will be increased to every 48 seconds for the F-15C Suite 4 OFP due for release in CY 2000. So every 48 seconds the transmitted PPLI interval will lengthen to 6

[18] Note that is an entry of 11 (6x11=66) which is still odd.



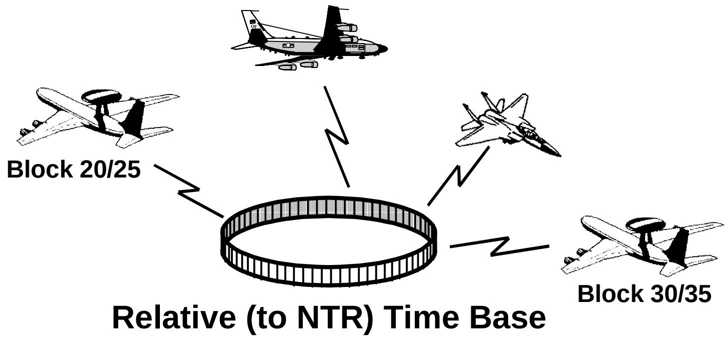
6.5-5 Synchronization – Individual Terminal and Platform Implementations

seconds. If there are no RTT NPGs assigned, then occasionally a PPLI will be preempted for an RTT. This is about once every 48 seconds too. The two preemptions are not synchronized, so on the average a 6 second interval will occur every 24 seconds, but occasionally, albeit rarely, two PPLIs in a row can be preempted and a 9 second interval can occur. So if the wing/unit manager receives complaints regarding occasionally long update times between PPLIs (i.e., "PPLI hops") he might look to see if there are RTT NPGs assigned to the network. But remember, only dedicated PPLIs can be preempted by RTTs, not contention PPLIs.

If its not NTR, the Class 1 terminal will RTT to other terminals based on receipt of their IJMS P-messages. It interrogates once every 12.8 minutes and will use any of its transmit time slots. So in mixed IJMS/TADIL J networks, at least one Class 2 or MIDS terminal equipped platform must be assigned to transmit IJMS P-messages and to receive the Class 1 terminal's IJMS transmissions so it can reply. This required P-message transmission and IJMS receipt is part of the mixed IJMS/TADIL J network design. All Air Force platforms can be so assigned[19].

If the Class 1 terminal equipped block 20/25 E-3 is NTR, the Class 2 and MIDS terminal equipped platforms will have to RTT to the Class 1 terminal. This is done by preempting P-message transmit assignments in the Class 2 and MIDS terminals. The Class 2 and MIDS terminal RTTs sent in the RTT NPGs are not in the proper format to be received by the Class 1 terminal. So the exchange of RTTs with the Class 1 terminal NTR will effect its perceived P-message update rate. When operating with dedicated access, the F-15, Rivet Joint and block 30/35 E-3 normally are assigned one slot per 12 second frame for their P-message transmissions. The P-message is preempted about once per 48 seconds for an RTT exchange. So once per 48 seconds the P-message update interval as received by the block 20/25 E-3 will lengthen to 24 seconds. The F-15s may transmit their P-messages with contention access. The access interval is typically 3 seconds. They are preempted about once per 48 seconds. If the F-15 is distant in range sequence from the block 20/25 E-3, several of the P-messages transmitted will not get through and those few missed P-messages due to preemption will not likely be noticed. However, missed RTTs due to contention effects may result in a somewhat lower time quality for the distant (in range sequence) F-15s. If the F-15 is close to the E-3 in range sequence missed P-messages due to

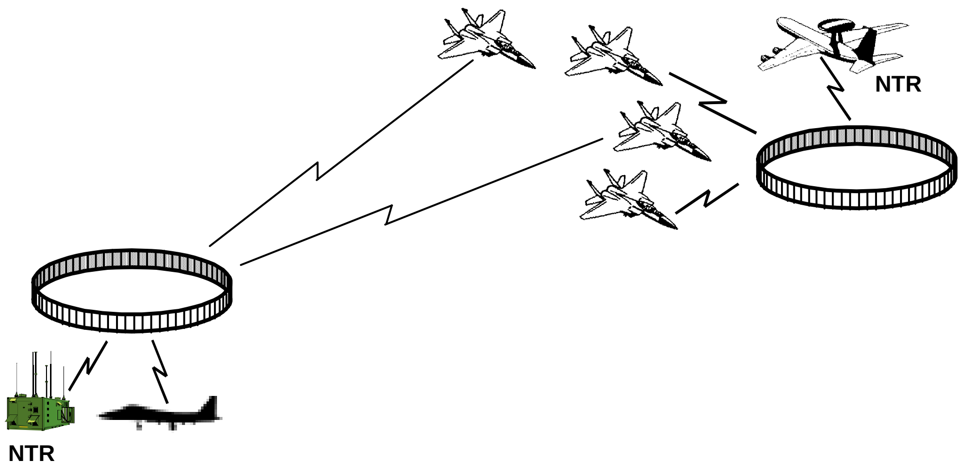
[19] Actually most platforms in general can be so assigned.



6.5-6 Synchronization – Individual Terminal and Platform Implementations

preemption will impact on the received rate, but the 3 second transmit interval is so short that the apparent average received update interval should be acceptable. Missed RTTs should be minimal and the resultant time quality high[20].

[20] Although not as high as if there were no missed RTTs.

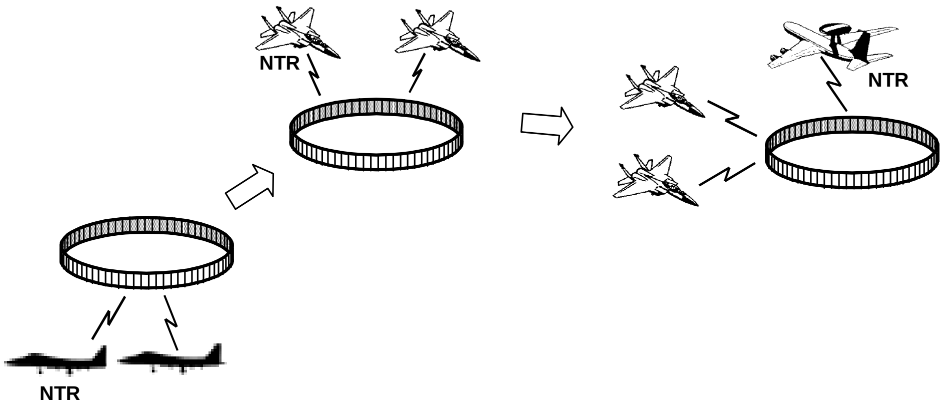


6.6-1 Synchronization – Multiple Net Time References (NTRs)

A relative time base network should have one, and only one, net time reference (NTR). What if it doesn't? Suppose at an air base two platforms are operating a Link 16 network on the ramp to test the platforms. Perhaps it's a CRE and a test F-15. The CRE is the NTR and so is transmitting the initial entry message, and they're using Zulu time. Suppose that unbeknownst to them, a flight of F-15s and an E-3 set out to operate a Link 16 network using the same cryptokey and network time. The E-3 is NTR. The E-3 enters time, sends a start net entry command to the terminal and begins to transmit the initial entry message. The flight of F-15s enter time and send a start net entry command to their terminals and begin to look for the E-3's initial entry message. But they are just as likely to enter on the CRE or the test F-15 as they are on the E-3! In the figure, half of the F-15s have achieved coarse synch and then fine synch with the E-3's network and half have achieved coarse synch with the CRE's network. However, all four F-15s think they've achieved synch with the E-3's network. It is very unlikely that the two independent NTRs will happen to have clock times within a fraction of a time slot (less than 1/128 th of a second) of each other, so terminals that have synchronized to one NTR will not be able to exchange messages with terminals that have synchronized to the other NTR. Thus, the mistaken F-15s can't see the E-3's PPLIs or tracks, or the PPLIs of the wingmen who are reporting fine synch! Neither do they see the CRE's PPLI (i.e., its a ground platform which is not processed by the F-15) or the PPLI of the F-15 on the ramp (PPLIs from F-15s which are not flight members and have weight on wheels set in their PPLI are not processed by the F-15). It is possible that the CRE and parked F-15 are using their own test network whose RTT NPG time slots are not a match for the RTT NPGs being used in the E-3's network. In this case the two mistaken F-15s will not achieve fine synch. If it so happens that they are using the same network[21], the two mistaken F-15s will achieve fine synch and see each other's PPLIs, but no other PPLIs. In either case the two mistaken F-15s have to wonder what's going on?

What's going on is two uncoordinated networks. It is the natural result of multiple NTRs in the same area using the same cryptokey and time base, but with the NTRs each

[21] It is normal that the F-15s use a standard network for daily training, and it is not unlikely that the test F-15 would be using that network.



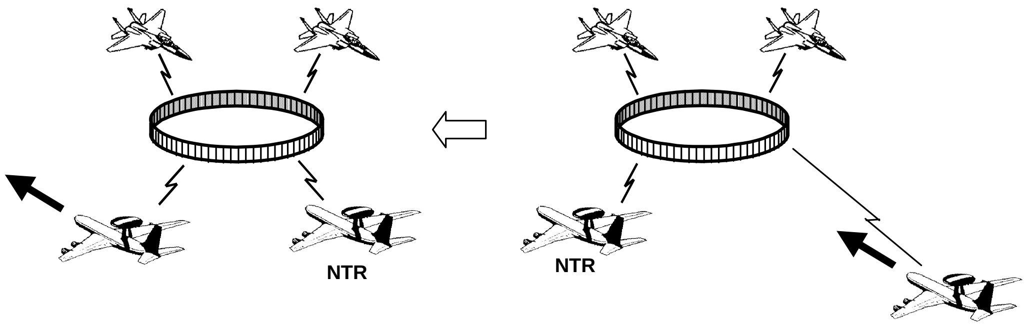
6.6-2 Synchronization – Multiple Net Time References (NTRs)

using their own time estimates and not correcting their terminal clocks to track a common external time reference. It could be caused much as described above if two F-15s in a package of F-15s intending to work together as a single autonomous network designate themselves as NTR. It is the reason we recommend that the F-15s not designate themselves NTR at the AFMSS. A pilot might use a DTM containing an initialization load with NTR set without realizing that it is set, resulting in two NTRs.

This issue is so important we'll provide several examples/situations.

Suppose there is a single network comprised of an E-3 acting as NTR with F-15s coming and going. Flights of F-15s take off from a base beyond line of sight of the E-3. They want to know that their Link 16 is working before they depart the airfield and want to use Link 16 on the way to the forward area with the E-3. One of the F-15s at the base getting ready to go designates itself as NTR and the rest of the flight enters on him. They fly to the forward area operating as an autonomous network. When they get there they want to join the E-3s network. They all perform a master reset, and start net entry. If they all do this at the same time, they'll all enter on the E-3 or an F-15 already working with the E-3. But suppose they stagger their master resets and start net entry times. One F-15 will execute a master reset and start net entry. He may enter on the E-3 or one of the F-15s working with it, or he may enter on one of his flight members who is still in the old network[22]. Since the clock degrades so slowly, even if the first F-15 to do the master reset is the NTR, the rest of his flight will hold a network together for quite some time. So to properly terminate their autonomous network, all of the flight members must execute a master reset[23] before any flight member attempts to enter on the new network, in this case the E-3 or one of the F-15s operating with the E-3.

[22] Remember, all F-15s are typically initialized to be initial entry message transmitters.
[23] Alternatively, they could all go radio silent, a transmit mode which will be discussed shortly, then do master reset and enter on the new network as each F-15 sees fit. Each member could come out of radio silence after doing his master reset.

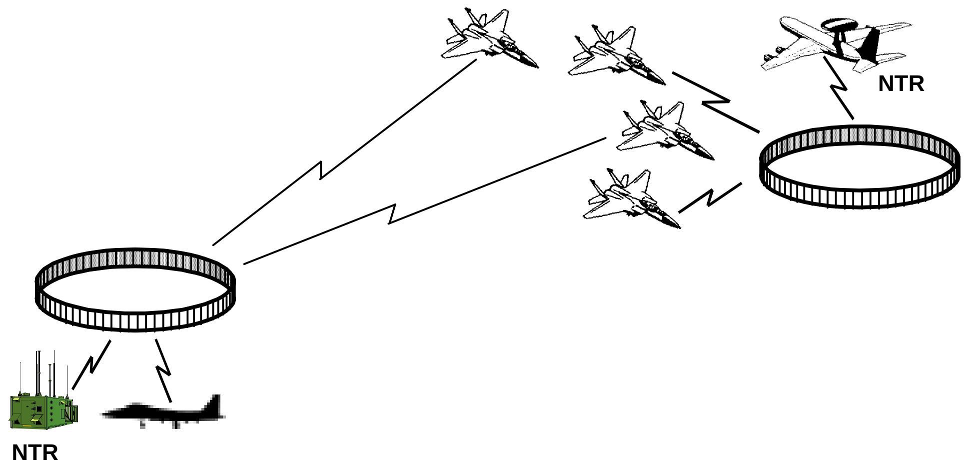


6.6-3 Synchronization – Multiple Net Time References (NTRs)

As a second example, suppose we have a network with an E-3 as NTR and F-15s operating with it, and a relief E-3 arrives (to the right above). That E-3 will have joined the network, but not as NTR. As the relieved E-3 begins to depart the area, he should deselect himself as NTR and the new E-3 should select NTR (to the left above). But, suppose the departing E-3 forgets to deselect NTR.

The new E-3 will have developed a good model of its clock error with respect to the network and, therefore, the old E-3, as it flew into the area. When it selects itself as NTR it does not use its raw clock for time, it uses its clock as corrected to the network time. This provides for a continuous network time as NTR changes occur. Both NTRs think they have perfect network time and tell that to the other participants via time quality in their PPLIs. At first they're both quite close in time so the "lie" doesn't cause a serious problem for the other network participants. So having multiple NTRs on NTR handover for a short time is fine. However, the old NTR's clock and the new NTR's corrected clock will begin to drift apart. This will tend to pull the network apart into two networks, one following one NTR and the other following the other. So <u>NTR handover should be carefully coordinated so that there are not multiple NTRs for more than a few minutes</u>.

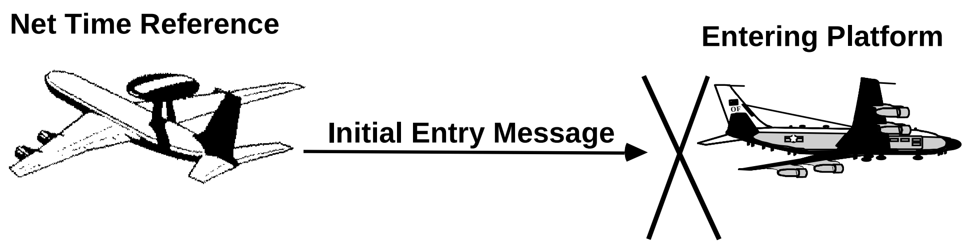
By the way, on NTR handover it's fine to have no NTR for a short time too. Remember that the corrected clocks will hold synch for a long time with no RTTs. So the time quality of the entire network will slip without an NTR, but it will take a long time to slip so badly as to preclude communication. This does not mean that a network should be operated a long time without an NTR. Some platforms, such as the F-15C, are critically dependent on JTIDS navigation, and the navigation quality is directly related to time quality. So we want as high a time quality as we can get to support JTIDS navigation, and <u>a network should not go without an NTR for more than a few minutes</u>. JTIDS navigation support is the main reason why we don't want more than one NTR for more than a few minutes either. The confused time synch resulting from two NTRs will compromise JTIDS navigation too. To summarize, in situations of NTR handover, it is OK to have two NTRs for a few minutes or no NTRs for a few minutes, so the terminal operators of the old and new NTR platforms do not have to worry about doing the switch at the same time, nor worry about who does it first. As long as they do it within a few minutes of each other things should be fine.



6.6-4 Synchronization – Multiple Net Time References (NTRs)

The third example is the general case of uncoordinated network operations in the same area with which we started. Such uncoordinated operations will result in great confusion. In addition, it will subsequently be seen that such uncoordinated operation of networks in the same area is against federal regulations. Frequency management procedures dictated by the NTIA[24] and FAA[25] for operations within the US&P[26] require network operations to be coordinated via a deconfliction server[27]. All operations must be posted on the server. Operations should not be taking place in your area without you being aware of them via the server. For each operation, the cryptokey being used is posted as well as its location. Using different cryptokeys is one way to ensure independent network operations in the same geographical area. <u>If, via the deconfliction server, you find that someone is operating Link 16 in your area (i.e., within JTIDS range[28] of any of your participants) with the same cryptokey, you must coordinate your use of Link 16 to ensure the proper operation of the two independent networks.</u> Independent networks in the same area are discussed further subsequently.

[24] National Telecommunication and Information Administration
[25] Federal Aviation Administration
[26] US and her possessions
[27] This is part of frequency management procedures which are described in detail subsequently.
[28] Normally 300 nm, but extended range mode will extend to line of sight (up to 500 nm).



6.7-1 Synchronization – Common Synchronization Difficulties

If a platform attempts to enter a network and achieve fine synch, but all of the network participants do not appear to be in the network, it may be due to uncoordinated network operations as just described. But what if the platform can't achieve coarse synch at all? The most usual reasons for failure to achieve coarse synch are mismatched cryptokey or time base.

When a platform starts net entry, his terminal will set up to receive the initial entry message of the NTR or a platform who has already entered the network. By set up we mean look for the next initial entry message which is at least one time uncertainty interval in the future based on his clock's time with today's cryptokey. To find that message the entering terminal must have its clock set to the network time within one uncertainty interval, using the network cryptokey and using today's segment of the cryptokey. If he does not achieve coarse synch, one of these conditions are not being met. Notice, the Class 2 and MIDS terminals use the initial entry slot for coarse synch independent of initialization data[29]. So an incorrect network design or a mismatch of network initialization loads will not normally[30] be the cause of a failure to achieve coarse synch.

A mismatch can be due to an error by the platform entering the network or by the NTR when he started up the network. For example, suppose a flight of F-15s form an autonomous network at their air base in preparation to fly to a MOA and then join up with an E-3. Everyone, the F-15s and the E-3, agree on the cryptokey title to use (e.g., AKAT 3109). The F-15s form their autonomous network just fine and fly out to work with the E-3. They all do a master reset, and then try to enter on the E-3 without any luck. Surely the E-3 has messed up since the F-15s have all been operating together just fine. Not so. All of the F-15s could just as well have been given the wrong cryptokey by maintenance. Obviously, it is critical that all participants be using the same cryptokey title. In addition, if the F-15s are using the correct cryptokey title, and they check with the E-3 by voice and find that they are too, there may be an error regarding which day's cryptokey. Within the title, the cryptokey will change each day. There are numerous ways each platform may be using the wrong day's cryptokey. These are covered in some detail in the cryptokey section. Again, it is critical that each participant is using today's cryptokey. For our example, if someone is not using

[29] The Class 2 and MIDS terminals can be directed to enter on other than the initial entry slot by initialization data, but this is not normally used in network designs.
[30] The Class 1 equipped block 20/25 can enter an initial entry slot other than the normal "A-00000-06" and/or a MAIN NET other than "0". There are circumstances for which this is proper (NATO normally uses a MAIN NET other than "0"). In such cases, a faulty network design or errors in initialization data entry can preclude network entry, by the Class 1 equipped participant on a Class 2 or MIDS terminal and vice versa.

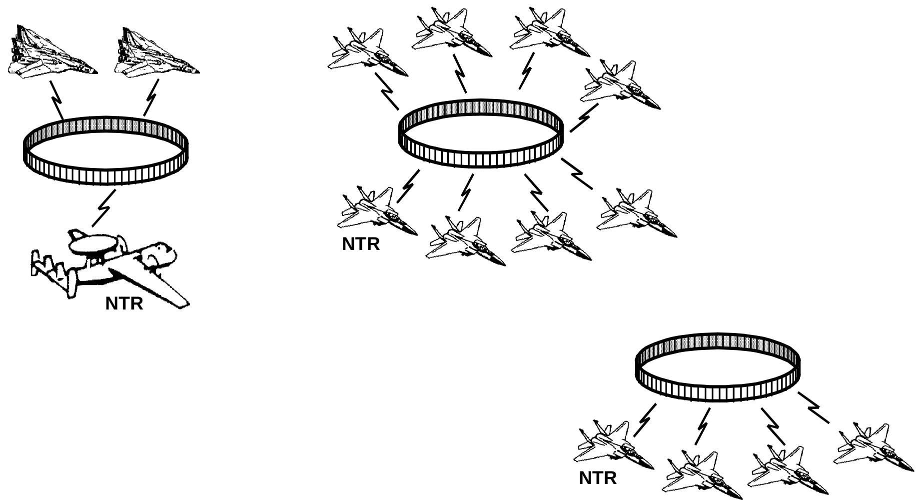
6.7-2 Synchronization – Common Synchronization Difficulties

today's cryptokey, it is most likely the E-3 since all four F-15s will have to be using the same wrong day's cryptokey if they've been successfully operating autonomously.

If cryptokey is not the problem it can be time. For example, it may be that the NTR or the entering platform has used a reference clock (e.g., a wall clock in a ground unit or his own watch) which has a significant absolute time error (e.g., a minute or more) to set his terminal's clock. If that time error exceeds the time uncertainty being used (i.e., one minute for the F-15s and Rivet Joint), the entering platform cannot achieve coarse synch. If the error is with the NTR and the established network, the F-15s can call a network participant, ask for a network time hack and enter the network time to fix this problem. If the error is more than one minute from Zulu time the Rivet Joint cannot! This is being changed in the Rivet Joint which will be able to set its clock in a forthcoming software release[31], but the right corrective measure is for <u>all network participants to obtain a good reference time hack prior to network operation and for platforms to be sure their clock time is within a few seconds of the reference time before starting net entry</u>.

Once in coarse synch, if a participant cannot achieve fine synch, it may be a mismatch of networks. RTT NPGs are not typically assigned the same time slots in different networks. If a flight of F-15s are working with an E-3, and the F-15s are all using one network and the E-3 is using another, the F-15s will all achieve coarse synch on the E-3 as NTR, but will not likely achieve fine synch. <u>If unable to achieve fine synch, a network entrant should ask the NTR or a network participant already in the network by voice which network it is using to ensure there is not a mismatch</u>.

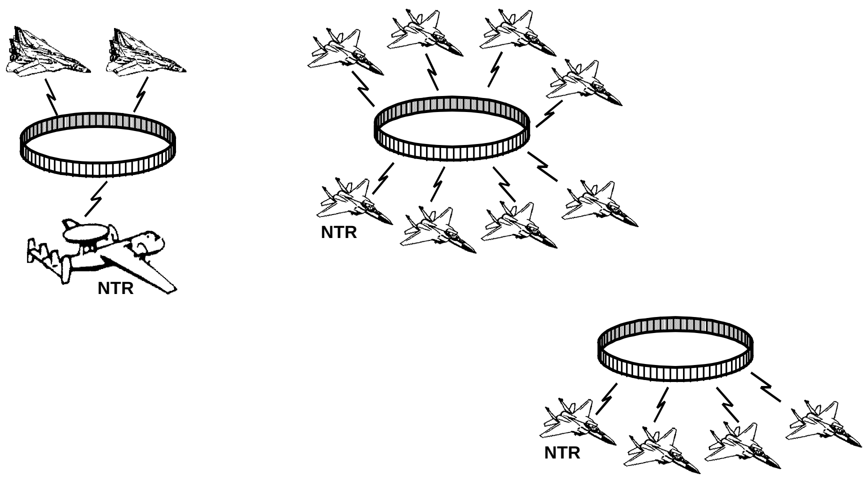
[31] Due for release in late CY 99.



6.8-1 Synchronization – Independent Networks in Close Proximity

There are many situations in which it will be necessary to operate independent networks in close proximity. Two approaches are available. They will be described by use of an example scenario, but are generally applicable. For the scenario we assume that the 366 WG has received Link 16 in its F-15Es. Today they will have two flights of F-15Cs from the 390 FS operating in one military operating area (MOA) and a flight of F-15Es from the 391 FS operating in another MOA on entirely different training missions. The F-15Cs and F-15Es will depart the base at different times and will likely return at different times. Furthermore, the two flights of F-15Cs may desire to operate as one network while flying out to the range, and then separate into two independent flights, one red and the other blue, for their training mission. All of this may be going on while the Navy at Fallon NAS is operating a Link 16 network with an E-2 and several F-18s in one of their MOAs. All of these operations will be within 300 nm of each other. All will be posted on the deconfliction server and be known to the 366 WG wing manager. How do we keep them independent?

The first way is by having each network use a different cryptokey. This is the likely way the 366 WG and the Navy at Fallon NAS will keep their daily training missions independent, with the Navy using Navy-unique cryptokeys and the 366 WG using Air Force-unique cryptokeys. It is also one way the F-15Es and F-15Cs on different training missions might stay independent, being from different squadrons. The wing will be provided several Air Force cryptokeys. One cryptokey could be assigned to each fighter squadron for it to use for its squadron-unique training missions. Cryptokey separation could even be the way the two flights of F-15Cs support independent network operations. The F-15 has the ability to change cryptokey used by their initialization data sets such that with a initialization load change they will change the cryptokey being used for the associated network. This capability, termed the cryptostep function, is described in detail in the cryptokey section. In our example, all eight F-15s would be given two network cryptokeys, one for the blue flight and the other for the red flight, and two initialization loads for the same network, one using the blue cryptokey and the other using the red cryptokey. To begin the operation all together they would all pick the same initialization load, either blue or red, it doesn't matter which.



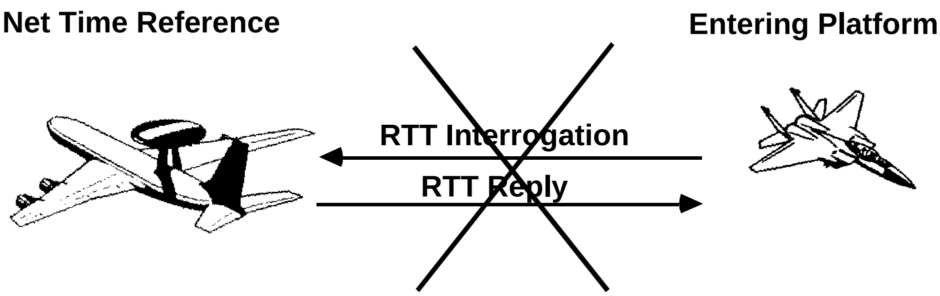
6.8-2 Synchronization – Independent Networks in Close Proximity

They would fly out to the MOA and if they had selected the blue initialization load, the red flight would do a master reset, change to the red initialization load and form their own network[32] using the red cryptokey. A problem with this approach is that it uses both initialization loads on the F-15's data transfer module (DTM), and there are other valid uses for the two loads such as to change navigation modes. Another problem is that it is beginning to demand that a great deal of cryptokey be created, stored and managed. Fortunately, an alternative procedure to achieving independent networks is available.

The second way to achieve independent networks is to use different time bases rather than different cryptokeys[33]. In our training scenario the eight F-15Cs would start up operations at the air base using Zulu time and fly out to the MOA. One flight, perhaps the blue flight, would do a coordinated master reset[34] to entirely withdraw from the red network, change their clock time to a new time base, perhaps Zulu plus one hour, and then form their own network on this new time base. As long as the new time base is more than one time uncertainty from the other time base, Zulu in this case, a new network is assured. However, to be safe, we recommend a base time difference of at least 10 minutes. Zulu time and local time can be used to limit confusion.

Use of different time bases to provide for independent networks has wide application. Some fighters[35] do not have the ability to change cryptokey while in flight as does the F-15. Yet it may be necessary to operate two independent Link 16 networks in theater between which the fighters can move while they are in flight. Use of offset time bases provides a means for doing this since platforms can typically set/reset their clocks. The only exception to this is the current Rivet Joint, and this will be changed by late CY 99.

[32] Designate one of the flight as NTR and have the other three flight members enter the network.
[33] There have been concerns expressed within the Air Force regarding the propriety of using this approach. The issue has been discussed with the National Security Agency (NSA) and the approach found to be acceptable, when use of different cryptokey (the preferred approach) is not convenient. This method is being taught by the Joint Multi TADIL School (JMTS) and is being used within the US.
[34] Any platform making a change of time base to leave one network and join another, should go to standby and then return to on (the equivalent to the F-15s master reset) to withdraw from the first network before resetting their clock and entering the new network.
[35] e.g., the F-14D and the UK Tornado



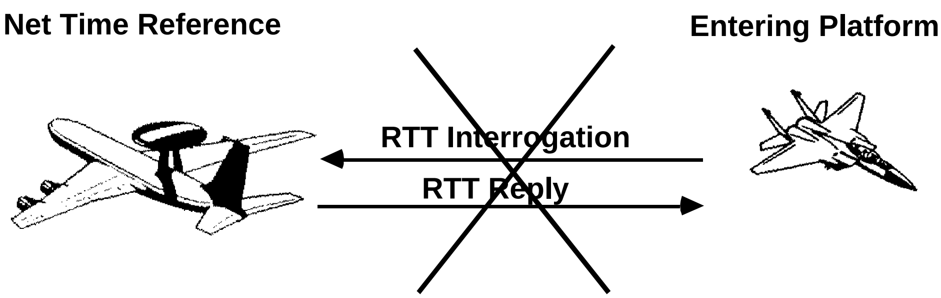
6.9-1 Synchronization – Radio Silent Ops, Passive Synch and RTT Range Limitations

There may be circumstances under which the emission of Link 16 signals is dangerous to a platform. The F-15 Class 2 and FDL terminals provide a transmit mode termed radio silent. In this mode the terminal will receive[36], but it will not transmit data. The terminal will transmit voice if the operator so chooses. These terminals are installed in the F-15s and Rivet Joint. In the E-3 Class 2 terminal there are two related modes. Data silent is equivalent to the F-15 Class 2 and FDL terminals' radio silent mode. The terminal will transmit voice if the operator chooses, but not data. The E-3 also has a radio silent mode. In its radio silent mode it will not transmit data or voice. In each of these modes it is necessary for the terminal to maintain fine synch so it can receive messages and be ready to quickly transmit when the transmit mode is changed back to normal. It must do this without sending RTT interrogation messages, and does so using passive synch.

Virtually all platforms provide their Link 16 terminal their position so the terminal can report their position out in their PPLI. Just how this is done is discussed in the navigation section. A terminal in radio/data silent is capable of achieving coarse synch without transmitting. Once in coarse synch the terminal is synchronized to within the propagation time of the initial entry message to the entrant. It normally uses RTTs to learn the propagation time. But without RTTs it can use its knowledge of its own position as provided by the host platform, the position of the participants already in the network, and the average speed of the radio wave propagation to estimate its clock error in much the same manner as it would use RTTs. Its just not quite as accurate (e.g. the host may not know its position all that well and the speed of propagation used is only an average).

Platforms are normally initialized as "primary users". This is part of the network design. A primary user will attempt to achieve the best time quality possible using RTTs. However, since an RTT exchange requires a round trip within a time slot, its range is limited to about 300 nm. This is compatible with the normal range mode, but what if the network is designed in the extended range mode and a platform is more than 300 nm from the participants with which it is trying to maintain fine synch? If it is initialized as a primary user it will keep trying to RTT and, upon failing, will slowly drop in time quality. This is because a primary user can only employ RTT for synchronization and never employs the passive synchronization method described above for radio silent users. To avoid this there is another user type termed "secondary user". A secondary user can employ both the passive synchronization method that the radio silent user employs and the RTT method that the

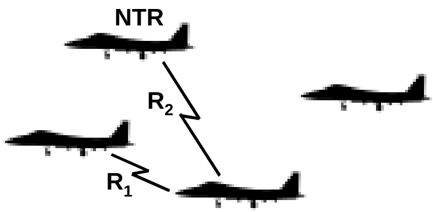
[36] Voice and data.



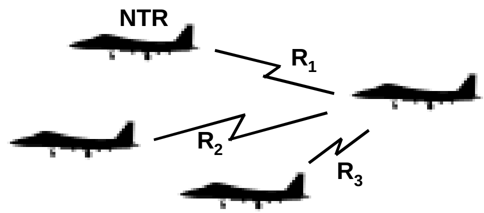
6.9-2 Synchronization – Radio Silent Ops, Passive Synch and RTT Range Limitations

primary user employs. However, a secondary user will only RTT if it will result in an improved position quality in its terminal's JTIDS navigation solution. It will not RTT to maintain best time quality so it cannot help other participants achieve a high time quality. This is why participants are normally initialized as primary users. However, if a secondary user is unable to exchange RTTs when necessary to maintain synch, it will still be able to passively synchronize (using the technique described above for radio silent users). In the case of an extended range network this is desirable, so for extended range mode networks, participants will be initialized as secondary users. If a wing/unit manager is asked by an operator (Rivet Joint or E-3 since the F-15 pilot doesn't see user type at the AFMSS) why he is seeing secondary user in his initialization data when he has been used to seeing primary user, it is probably because the network is in extended range.

Suppose that a participant is approaching a network being operated with the normal range mode, is further than 300 nm from any network participant, but has started his net entry process. If he is within line of sight of a network participant who is transmitting the initial entry message, he can achieve coarse synch although with a considerable time error. In addition, he will see the messages being transmitted by the network participants even though they are beyond the normal range (i.e., 300 nm) since his time error will favor their reception (i.e., the terminal thinks its within 300 nm of the participants). If he is a secondary user and subsequently achieves fine synch, his receipt from the network participants will become spotty and then possibly disappear since he has removed the favorable time error. If he is a primary user (normal for networks operated in the normal range mode) he will not achieve fine synch since he is too far away to exchange RTTs with any participant. So if a participant is approaching a network being operated in the normal range mode, achieves coarse synch, but cannot achieve fine synch, he should check to see if he is within 300 nm of a network participant with whom he can exchange RTTs. If not, he will have to wait until he is before he should expect to achieve fine synch.



$|R_1-R_2|<200$ ft.



$|R_1-R_2|<200$ ft.
$|R_1-R_3|<200$ ft.
$|R_2-R_3|<200$ ft.

6.10-1 Synchronization – Entrants in Close Proximity (Fighters)

If several participants are attempting to form a network and two or more are in close proximity there can be problems. It has previously been stated that if two participants transmit in the same time slot, a receiving participant will receive from the closest participant. This is true if the participants are not equidistant in range from the receiving participant. If the ranges to the transmitting participants are within about 200 ft. of each other, the receiving participant will receive from neither. This is normally a rare situation, but may well be the case when a flight of fighters form a network while parked together on the ramp.

Suppose we have a four-ship flight of F-15s parked close together and that they attempt to form a network with staggered net entries. The NTR will check/correct time, start net entry, achieve fine synch and begin to transmit the initial entry message. The first entrant will check/correct time, start net entry, receive the initial entry message from the NTR and achieve course synch, and RTT to the NTR and achieve fine synch.

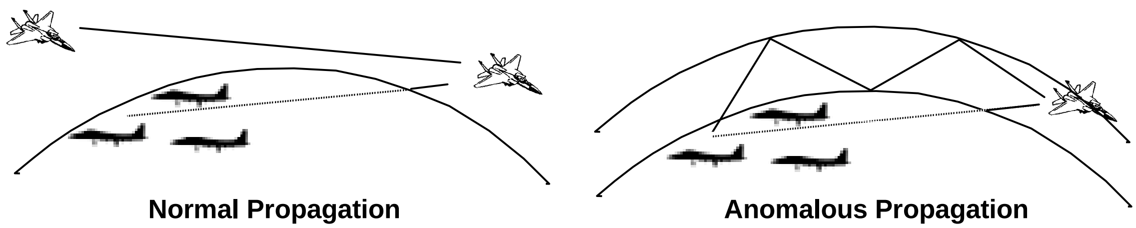
The second entrant will check/correct time, start net entry and look for an initial entry message. But all of the F-15s are initialized to transmit the initial entry message since we are using contention access and we never know just who the NTR will be or whether or not an particular F-15 will be within line of sight of the NTR. Suppose the ranges from the second entrant to the NTR and the second entrant to the first entrant are within 200 ft of each other. For those initial entry slots in which both participants transmit the initial entry message, the second entrant will receive neither. But remember, the initial entry transmitter will only transmit in every other initial entry slot on the average, so eventually a slot will occur in which the first entrant doesn't transmit and the second entrant will receive from the NTR On any particular attempt it will have a 50% probability of succeeding. So on the average, given a one minute uncertainty, it will take 3 minutes to achieve coarse synch rather than the more normal one minute.

The third entrant now checks/corrects time and starts net entry. Suppose that the first two entrants are positioned so that their initial entry messages and those of the NTR are all within 200 ft in range from the third entrant. The third entrant will have to wait until he finds an initial entry slot in which neither the first or the second entrant is transmitting before he will be able to enter on the NTR. This will occur with about a 25% probability so the

6.10-2 Synchronization – Entrants in Close Proximity (Fighters)

average time to enter will be extended to 7 minutes. This is just the average, it could take longer. To avoid the problem of entrants in close proximity interfering with each other's initial entry message, the best approach is for pilots to coordinate their entry (i.e., start net entry at about the same time). That way they all have achieved coarse synch before any has achieved fine synch and can interfere. However, if staggered entry is performed on occasion and the pilots complain about occurrences of slow net entry when parked close together on the ramp, the wing/unit manager should suggest that once in the network (i.e., fine synch) the non NTRs switch their terminals to radio silent until all of the flight has achieved fine synch. This will prohibit their transmission of the initial entry message and their interference with the NTR's initial entry message.

Normal Radio Line of Sight Estimate (4/3 earth); LOS (nm) = $1.23\sqrt{h\ (ft)}$;
Normal atmospherics can extend (reduce) this some, but seldom more than 10%. e.g., h = 20000 ft, LOS = 174 nm



6.11-1 Synchronization – Propagation Effects

Normal line of sight is established by the curvature of the earth and normal atmospherics. Atmospherics normally run from dense air at low altitudes to less dense at upper altitudes, and this provides some bending of the radio signal with some advantage in range. The bending causes the radius of the earth to look greater than it is by 4/3.

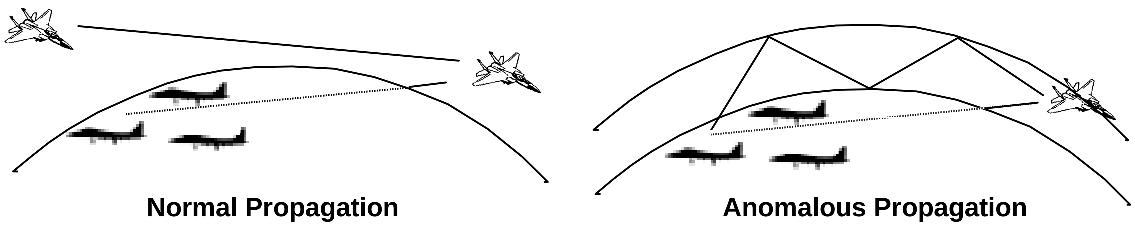
The figure provides a simple formula for computing line of sight range to the earth's surface as a function of altitude with a 4/3 earth. The range between two airborne platforms is the sum of the two ranges to the earth's surface. If a flight of F-15s are operating a CAP[37] in the forward area at 20000 ft., they would normally have line of sight to the surface at up to 174 nm. Of course this does not include the effects of topography (e.g., a mountain between the F-15s and the point in question on the surface).

We'll discuss the issue with an example. We are operating a network with an E-3 as NTR and a flight of F-15s on CAP in the forward area. Suppose a flight of F-15s is on the ramp at an air base to the rear preparing to fly out to the forward area and relieve the current F-15 CAP. The current CAP is 350 nm forward of the air base and about 150 nm forward of the E-3 orbit. The network is designed to operate in the normal range mode[38]. The F-15s on the ramp are certainly not within line of sight of the F-15s on CAP, and also out of JTIDS range, but they may be in line of sight of the E-3 depending on its location in orbit. The relieving F-15s would like to enter the E-3's network if possible right on the ramp. If they can't, they'll form an autonomous network on the ramp, fly out to the forward area and once in range of the E-3 or the F-15s to be relieved take down their network and come up on the E-3's network. So the relieving F-15s try to enter the E-3's network. Soon after they declare coarse synch, but they don't see the E-3's PPLIs, they see the forward flights' PPLIs! And they can't achieve fine synch. How can this be?

Weather conditions can form layers of air between which there are steep density gradients. This can cause radio signals to bounce off the boundary between the layers and their range is extended as shown in the figure. In our example, the E-3 is not within line of sight, but due to anomalous propagation termed ducting, a forward F-15's initial entry message has gotten through. Once in coarse synch with the forward F-15s, the F-15s on the ramp can receive their messages, but cannot exchange RTTs with them due to range and line of sight limitations.

[37] Combat Air Patrol
[38] At a maximum data exchange range of 300 nm.

Normal Radio Line of Sight Estimate (4/3 earth); $\text{LOS (nm)} = 1.23\sqrt{h\ (\text{ft})}$; Normal atmospherics can extend (reduce) this some, but seldom more than 10%. e.g., h = 20000 ft, LOS = 174 nm



Normal Propagation **Anomalous Propagation**

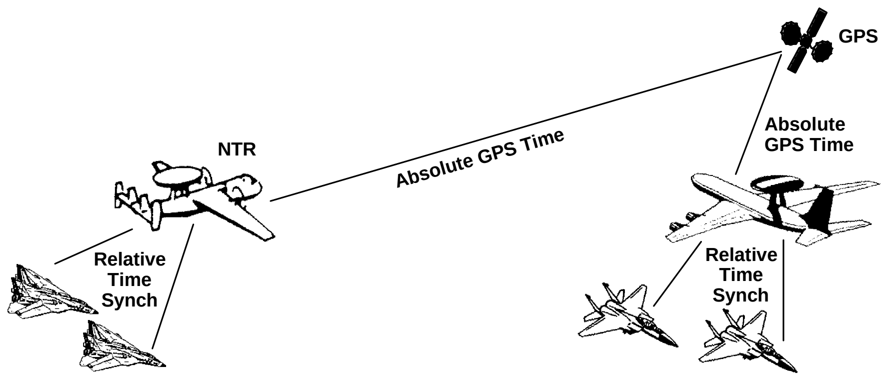
6.11-2 Synchronization – Propagation Effects

What should the pilots do?

Such anomalous propagation has been experienced by F-15s during a deployment to the Persian Gulf. In that area of the world and in the far east, it is not an unusual phenomenon. It affects JTIDS navigation as well as synch and is discussed again in the navigation section. It is a common phenomenon to experienced data link users such as the Navy[39], but was new to the Air Force Link 16 users during the Gulf deployment. During the Gulf deployment it was found that if the F-15s waited until they were above 20000 ft of altitude before entering the E-3's network, they were both above the layering with its associated ducting and within line of sight of the E-3. Alternatively, they could have formed their own autonomous network while on the ramp with an offset time to ensure independence from the forward F-15s until they were above 20000 ft and within line of sight and RTT range[40] of the E-3 or the forward F-15s to properly join their network.

<u>If operators/pilots experience synchronization problems, normal corrective measures do not work, they are operating where atmospherics may be a problem, and they see link performance which seems to defy normal rules for line of sight and the range mode of the network in which they are operating, they should suspect anomalous propagation and, for synch, can take steps to ensure that they enter a network which does not exhibit such propagation difficulties. For F-15s, it has been found that anomalous propagation effects are not experienced when operating above 20000 ft of altitude[41].</u>

[39] In fact, E-2s have refractometers on board and measure the refractive index on their way up to altitude so they have a good idea of what to expect for data link behavior.
[40] About 300 nm.
[41] Although this is admittedly based on very limited experience.



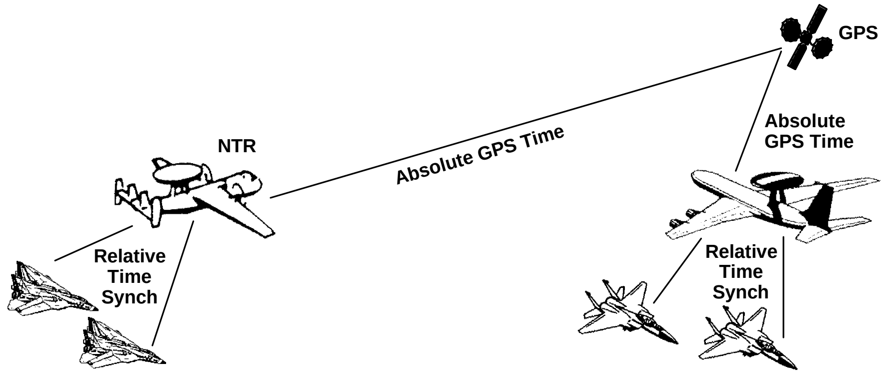
6.12-1 Synchronization – External Time Based Networks

In theater suppose we have Air Force/Army operations to the east and Navy/Marine operations to the west[42]. They all wish to operate Link 16. However, the operations to the east do not always have a platform within line of sight of a platform from the operations to the west, so they cannot maintain a single Link 16 network. This dictates the formation of two independent networks, one in the east and one in the west. This is the case despite the fact that there are often platforms within line of sight of both operations, and platforms from one operation often move to work with the other (e.g., fighters for air support or Rivet Joint for intel support). Platforms in the two networks are unable to exchange information, independent of their proximity (e.g., F-15s in the eastern network and F-14Ds in the western network flying close together in the central region cannot see each others PPLIs). Platforms moving between the two have to drop from one Link 16 network and enter the other. Wouldn't it be nice if we could operate a single network despite the fact that there was prolonged periods for which participants of one were not within line of sight of participants of the other?

At an air base we have fighters going and coming at different times doing daily training, some returning from cross country flights. It is not possible to coordinate and maintain a single network due to line of site constraints between all of the fighters, and to coordinate on the entry of fighters returning from cross country flights into a single network. Wouldn't it be nice if they could all operate in a seamless network and see each others PPLIs if and when they came within line of sight?

An external time base can make the above desires possible. Its use will be described with an example similar to the first situation above as shown in the figure. The E-3 in the east is not always within line of sight of the E-2 in the west, although they can be for some of their orbit. Both the block 30/35 E-3 and the E-2 have GPS and have been given the capability to use its time as an external time reference (ETR) for Link 16. They must be enabled to use ETR by the terminal operator. For the E-3 this is done via the control monitor set (CMS) with a EXTERNAL TIME STD setting by the communication technician, and must be done before starting net entry. ETR should not be selected if the network is to be a relative time based network[43], so <u>for daily training, the wing manager, acting as network manager, must decide which time base to use, relative or external, and</u>

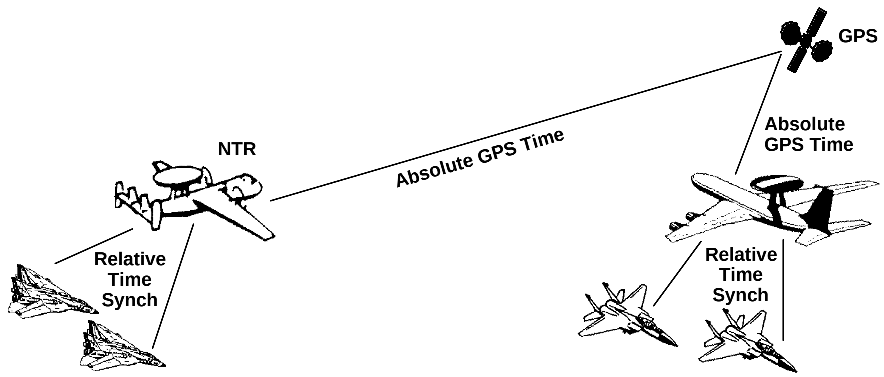
[42] This could just as well be two carrier battle groups.
[43] Why will be explained subsequently



6.12-2 Synchronization – External Time Based Networks

inform his ETR capable platforms. In the example it would be the E-3 and E-2. The block 30/35 E-3 is the only Air Force platform to date to implement an ETR capability. To begin our description of the ETR operation we'll assume that when the network is formed the E-3 and E-2 are within line of sight. Then we'll explain the difference if they are not.

A network participant must be designated NTR, the E-2 in the example. The E-2 will enable ETR, check/correct time to approximate GPS time, and start net entry. The terminal will be provided a time and time quality by the GPS interface. It will synchronize with the GPS time (i.e., build a model of the error between its clock and the GPS time) and declare fine synch. It will begin to receive and transmit, including transmission of the initial entry message and its PPLI with a time quality commensurate with that being provided to it by the GPS interface. [Note, if the network was not to be operated with an external time base and the relative time base was different from GPS time (e.g. local time), it would be essential that ETR was disabled, otherwise the NTR would be synchronized with GPS (Zulu) time while other participants were trying to enter on local time.] The F-14Ds which do not have an ETR capability will check/correct their time, start net entry, and achieve coarse and then fine synch, just as they would in a relative time based network except that the time base must be GPS time (i.e. Zulu time). The E-3 will check/correct time, enter a time uncertainty (e.g., 30 seconds) and start net entry. Its terminal will acquire coarse synch on the E-2 or F-14Ds just as it would in a relative time based network except that the time base must be GPS time (i.e., Zulu time). Once in coarse synch the terminal will achieve and maintain fine synch either by RTTs to other participants such as the E-2 or by reference to the GPS time input, whichever is most accurate. This will normally be the GPS time input, but if its GPS receiver begins to report a lowered time quality the E-3 terminal will automatically begin to RTT to the E-2, or any network participant with better time quality. [Note that if operating a relative time network whose time is close to but different than GPS time, once in coarse synch, if ETR is enabled, the terminal will see incompatible times of high quality, one from the network and the other from the GPS interface. This incompatibility can lead to a degradation of its time quality and that of the network. That is another reason why ETR should be disabled if operating a relative time base.] Once in fine synch the E-2 will also be able to use both the GPS time input and the network time via RTTs, even though it is NTR. If its GPS time quality begins to be reported with a lowered quality it will automatically begin to RTT to the E-3, or any participant of better quality. The F-15Cs which do not have an ETR



6.12-3 Synchronization – External Time Based Networks

capability[44] will check/correct their time, start net entry and achieve coarse and then fine synch, just as they would in a relative time based network except that the time base must be GPS time (i.e. Zulu time). The result of all of the above is a GPS time based network with both the E-2 and the E-3 maintaining synch with ETR time and the fighters maintaining synch with them. If the E-2 and E-3 should now fly out of line of sight of each other for a prolonged time, the network will remain synchronized with ETR time (e.g., as F-15Cs and F-14Ds approach within line of sight they can see each others PPLIs).

If the network is to be formed when the E-3 is not within line of sight or JTIDS range[45] of a network participant already in synch, the E-3 will have to designate himself NTR. If the E-3 then comes within line of sight of the other operation, the fact that there are two NTRs is not a problem with an external time based network. In fact, all ETR equipped platforms could make themselves NTR and once they entered the network their operation would be equivalent to ETR participants which hadn't made themselves NTR. However, if a platform which has not yet entered the network is designated NTR, and if its GPS time quality is not of sufficient accuracy to support initial achievement of fine synch, being NTR would deny this platform the chance to enter on the initial entry messages of other network participants. This is because a terminal that is trying to enter a network as an NTR using ETR never listens for initial entry messages from other terminals; it always uses its own GPS to get started . So it would be stuck, due to its bad GPS. If this terminal's operator deselected NTR he could then enter the net on an initial entry message from some other user, and achieve fine synch via RTT, overcoming his own lack of a good GPS signal. Therefore, <u>in general, a platform in a GPS time based network should not designate itself as NTR unless it is necessary for it to enter the network (i.e., being the first network participant or not being within line of sight or JTIDS range of any active network participant)</u>.

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[44] The F-15Cs do not have GPS at all. Because they do not have an ETR capability, the F-5Cs operating into and out of an air base must either coordinate among training flights to establish and maintain a single network, or use a ground site which can be a stable NTR (i.e., all day) such as the 726 ACS CRE at the 366 WG. Both the F-15E and F-16 have GPS and will be equipped with an ETR capability.

[45] Probably only a potential problem if operating in the normal range mode.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
JNETWORK/AFBO0013A/04MAR98/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
JCRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

6.13-1 Synchronization – OPTASK LINK Message

To date, a relative time base has been the normal mode of operating Link 16 networks and the normal time base is Zulu time. Therefore, if there is no mention of time base in the OPTASKLINK we suggest that a relative time base of Zulu time be assumed. If a relative time base is selected, all ETR capable platforms must disable ETR (e.g., for ETR the E-3 communication technician should not select EXTERNAL TIME STD) and one, and only one, NTR must be designated. However, it may be desirable to use other than Zulu time in a network to ensure network independence. In some circumstances the most appropriate means for doing this is to coordinate by voice. A good example would be a two flights of F-15s operating as one network while flying out to a MOA and then splitting into two independent networks to conduct training operations. But there may be instances for which the time offset should be coordinated by OPTASK LINK. For this we suggest the use of the general text SETID, for example

GENTEXT/THE LINK 16 NETWORK WILL EMPLOY LOCAL TIME AS THE TIME BASE RATHER THAN THE NORMAL ZULU TIME.//

In the example OPTASK LINK message above, a relative time base of Zulu time is assumed.

As more platforms become equipped with ETR, it may be more heavily utilized. If an external (GPS) time base is selected, all ETR capable platforms should enable ETR (e.g., for ETR the E-3 comm tech should select EXTERNAL TIME STD), any designated NTR must be ETR capable, and there can be more than one NTR if necessary (i.e., a set of participants cannot achieve coarse synch with an existing part of the network due to line of sight or range

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
JNETWORK/AFBO0013A/04MAR98/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
JCRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

6.13-2 Synchronization – OPTASK LINK Message

limitations). The OPTASK LINK message provides no specific SETID to indicate time base. Therefore, we suggest use of a general text SETID. For example,

GENTEXT/NETWORK WILL EMPLOY EXTERNAL TIME REFERENCE USING GPS TIME. PLATFORMS IMPLEMENTING ETR SHOULD ENABLE. ANY NTR MUST BE ETR CAPABLE.//

The example OPTASK LINK in the figure assumes a relative time base.

NTR is a network task assigned via the DUTY SETID. In the figure, the E-3 from the 964 ACS with voice call sign Magic has been designated as NTR. For relative time based networks one, and only one, NTR should be specified. For external time base networks, at least one NTR should specified via the OPTASK LINK message, but platform operators of ETR capable platforms will have some latitude in designating themselves NTR based on the geographical situation. Initial entry transmitters are designated as part of the network design.

In garrison responsibilities in support of operations managed by personnel other than at wing:

10. Consult the deconfliction server to determine if other networks are being operated within line of sight and range of any of the platforms in your network. If so, independent operations must be ensured throughout the use of either cryptokey or time offset. Time offset requires the use of a relative time base for at least one of the networks involved. The offset should be at least 10 minutes. Also, remember, the Rivet Joint must use Zulu time until new software due in late CY 99 is released. Reference: para 6.8-1,2

11. Decide whether to use a relative or external time based network. To use an external time based network at least the net time reference (NTR) must be capable of using GPS time as an external time reference (ETR). The block 30/35 E-3 is currently so capable. The use of a relative time base will be assumed by network participants.

    a. If using a relative time based network, all ETR capable platforms should disable ETR. In addition, a Zulu time base will be assumed. If a different time base is to be used for network independence, it may be best to coordinate by voice (i.e., subdividing a package of fighters into to two independent networks). If the OPTASK LINK is appropriate, we suggest the use of the GENTEXT SETID, for example Reference: para 6.13-1

    GENTEXT/THE LINK 16 NETWORK WILL EMPLOY LOCAL TIME AS THE TIME BASE RATHER THAN THE NORMAL ZULU TIME.//

    b. If an external time base is to be used, the network participants must be informed via the OPTASK LINK message. We suggest the use of the GENTEXT SETID for this too, for example Reference: para 6.13-2

    GENTEXT/NETWORK WILL EMPLOY EXTERNAL TIME REFERENCE USING GPS TIME. PLATFORMS IMPLEMENTING ETR SHOULD ENABLE. ANY NTR MUST BE ETR CAPABLE.//

12. If the network is to be relative time based, one, and only one, participant must be designated net time reference via the OPTASK LINK. The DUTY SETID is used, for example, Reference: para 6.13-2

    DUTY/964 AWACS:E-3:MAGIC/NTR//.

    If it is an external time based network one NTR should be designated, but other ETR capable participants can designate themselves NTR if necessary to enter the network (i.e., if they are not within line of sight or are not within range of other active network participants).

13. Most network participants are designated initial entry message transmitters as part of the network design. However, when entering on an initial entry transmitter other than the NTR, coarse synch may take longer to achieve. Reference: para 6-4

14. We have the following recommendations regarding synch:

    a. All network participants should obtain a good time hack premission and ensure that their terminal clock is set within a few seconds of the coordinated network time prior to net entry. For an ETR based network the time hack should be Zulu time. Reference: para 6.12-3

    b. F-15s should not designate themselves NTR at the AFMSS, but rather enter NTR in the cockpit just prior to forming the network. NTR selected as part of the initialization data on the DTM can inadvertently lead to multiple NTRs and their attendant problems. Reference: para 6.5-1

    c. When first entering a network, the F-15s should enter time so the flight processor will send a one minute uncertainty to the terminal increasing the likelihood of entry. Reference: 6.5-1

6.14-1 Synchronization – Wing/Unit Manager Checklist

This checklist is an extension of that started in the Network Management I section. It will be extended in subsequent sections and summarized in Network Management II.

14. We have the following recommendations regarding synch (continued):

d. The block 20/25 E-3 should always enter a time uncertainty which is a odd multiple of 6 seconds to ensure they cannot become synchronized with the TADIL J initial entry message being transmitted by a Class 2 terminal equipped platform.Reference: para 6.5-4

e. To properly terminate their operation in one network and join/form another, a flight of F-15s should all perform a master reset before any one of them attempts to enter the new network, otherwise they may reenter on the old network. Reference: para 6.6-2

f. When it becomes necessary to handover the NTR function from one platform to another, the handover can be somewhat sloppy with there being two or no NTR for a short time, but the time should be no longer than a few minutes. This time duration is paced by navigation quality, not time quality itself. Reference: para 6.6-3

g. To avoid the problem of entrants in close proximity interfering with each other's initial entry message, the best approach is for F-15 pilots to coordinate their entry (i.e., start net entry at about the same time). That way they all have achieved coarse synch before any has achieved fine synch and can interfere. However, if staggered entry is performed on occasion and the pilots complain about occurrences of slow net entry when parked close together on the ramp, the wing/unit manager should suggest that once in the network (i.e., fine synch) the non NTRs switch their terminals to radio silent until all of the flight has achieved fine synch. Reference: para 6.10-2

h. If operators/pilots experience synchronization problems, normal corrective measures do not work, they are operating where atmospherics may be a problem, and they see link performance which seems to defy normal rules for line of sight and the range mode of the network in which they are operating, they should suspect anomalous propagation and, for synch, can take steps to ensure that they enter a network which does not exhibit such propagation difficulties. For F-15s, it has been found that anomalous propagation effects are not experienced when operating above 20000 ft of altitude. Reference: para 6.11-2

6.14-2 Synchronization – Wing/Unit Manager Checklist

Coarse Synchronization

1. If after a start net entry command a participant is unable to achieve coarse synch it is most likely a time or cryptokey related problem. Check to be sure that:

   a. The participant's clock time is correct (i.e., set to the time base that has been coordinated upon). If necessary, obtain a time hack from the NTR or another active network participant by voice. If the participant is the first to enter the network, this may reveal that the NTR has incorrect time. Reference: para 6.7-2

   b. The participant's time uncertainty is large enough. If not, if possible, try a larger time uncertainty. For the E-3 this can be entered by the comm tech. For the F-15 pilot entry of time will overwrite the short default uncertainty of 6 seconds per day since synched with a 1 minute uncertainty Reference: para 6.7-2

   c. The participant's cryptokey is correct. This includes assuring that the correct title (e.g., AKAT 3109) is being used and that the right day's cryptokey is being used (e.g., correct date or current cryptoperiod designator, to be discussed further in cryptokey section). Reference: para 6.7-1

   d. If the participant is the first to enter the network, ensure that the NTR's cryptokey is correct by voice.Reference: para 6.7-1

2. If time and cryptokey are correct, and coarse synch cannot be achieved, ensure that the participant is within line of sight of a network participant which is an initial entry message transmitter. Reference: para 6.7-1

3. If time and cryptokey are correct and the participant is within line of sight of an initial entry transmitter, we have found occurrences of loose or fully disconnected antenna cables, even in F-15s. These should be checked.

4. If the range to the NTR may be within 200 ft of the range to other participants already in the network (e.g., other F-15s in the flight on the ramp who have already achieved fine synch), long entry time may reflect a staggered network entry process and interference of the receipt of the NTRs initial entry message. Suggest a coordinated entry process whereby all F-15s start net entry at about the same time so all will achieve coarse synch before any (except the NTR) achieve fine synch. If staggered entry attempted, request other participants already in the network go to radio silent until entering participant achieves coarse synch so that will not interfere with the NTR's initial entry message. Reference: para 6.10-1

5. If the NTR is ETR capable, and the network is to be operated with a relative time base which is significantly different than GPS (Zulu) time, check that the NTR has not enabled ETR. If he has, the network time base is GPS time, not the correct time base. Reference: para 6.12-3

6.15-1 Synchronization – Network Troubleshooting

This subsection presents a network troubleshooting guide. It starts with network synchronization as just described in this section. It will be expanded upon in subsequent sections and summarized in Network Management II.

Fine Synchronization

6. If after coarse synch has been achieved, a participant cannot achieve fine synch, it may be due to one of the following:

   a. The participant is using an incorrect network initialization data set, and the RTT NPG time slot assignments in his network do not match those in the correct network (i.e., the network that has been coordinated upon). Check with a network participant by voice. If the participant is the first to enter the network, it may be that the NTR is using an incorrect network initialization data set. Check with him by voice. Reference: para 6.7-2

   b. There may be another network operation in progress which has not been coordinated with to ensure independence. In some cases this will be clear since PPLIs from unexpected participants will be seen once in coarse synch. In other cases, the PPLIs of the "offending" participants aren't seen. Diagnosing this is more difficult, but knowledge of past offenders may help. In any case, the solution to the problem is to time offset the network which is being formed, and to contact the offending participants to avoid the problem in the future. Reference: para 6.6-1

   c. The participant may be initialized as a primary user and not be within RTT range (300 nm) of a network participant. Check received PPLIs to see if they are within RTT range. If not, select radio silent for about 5 minutes and then switch back to normal transmit. In the 5 minutes, the terminal should passively achieve fine synch and a clock model adequate to communicate until the participant is within RTT range. Reference: para 6.9-1

   d. There may be anomalous propagation effects present. Check received PPLIs to see if they defy normal line of sight conventions. If so, suggest wait until above 20000 ft altitude (i.e., above the propagation effects) before attempting to enter the network. Reference: para 6.11-2

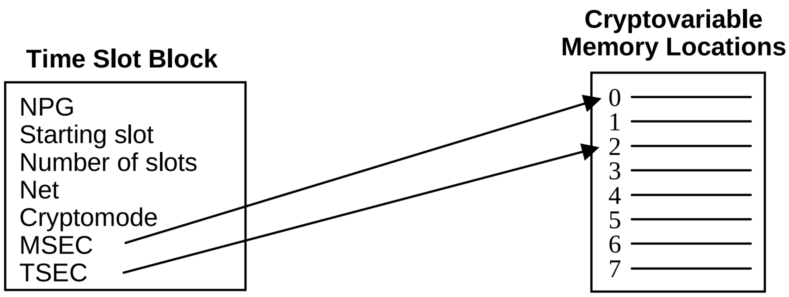
Systemic Problems

7. If the network time quality appears to be dropping and there has recently been a handover of the NTR function, check to see that the new NTR has so selected himself (i.e., has a time quality of 15). For F-15s which do not display ownship time quality, position quality will follow ownship time quality down, so one reason for a dropping position quality is a dropping time quality. If the new NTR has so selected himself, check to make sure the old NTR has deselected himself (or is gone!) If he has not, that too could cause a dropping of both time and position quality as each participant tries to resolve the two differing NTR sources. Reference: para 6.6-3

8. If the network is relative time based and a participant's time quality is fluctuating, if the participant is ETR capable, check to be sure he has not enabled ETR. Reference: para 6.12-2

6.15-2 Synchronization – Network Troubleshooting

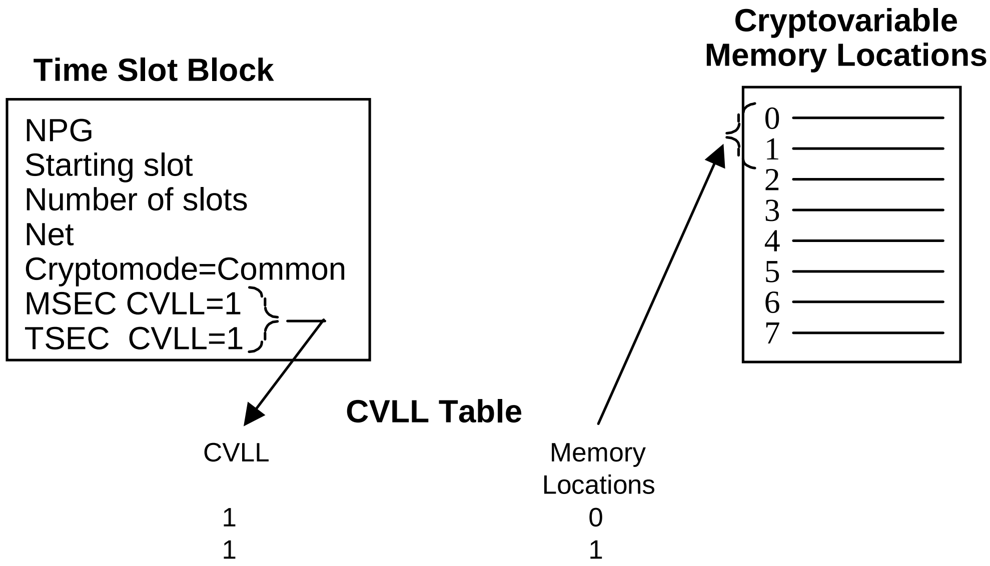
7.0 Cryptokey Utilization



7.1 Cryptokey Utilization - Cryptomodes

Link 16 terminals, at least as used by the Air Force, contain 8 locations in which to load cryptokey. These are labeled locations 0 through 7. When a time slot block is assigned to a Network Participation Group (NPG), the assignment must specify how the cryptokey is to be used by the assignment. There are two functions which must be considered. The first is the basic encryption of the information being exchanged (e.g., track reports for the Surveillance NPG). The cryptokey used for this is called the message security cryptokey, or MSEC for short. The second function is the determination of the frequency hopping pattern and related transmission characteristics. The cryptokey used for this is called the transmission security cryptokey, or TSEC[1] for short. A different cryptokey can be used for each function as shown in the figure, and this is called the partitioned variable cryptomode. In the figure the cryptokey loaded into memory location 0 would be used for the message security and the cryptokey loaded into memory location 2 would be used for the transmission security. The cryptomode would be set to partitioned. It is also possible to use the same cryptokey for both functions. This is called the common variable cryptomode, and it has become the norm for Link 16 networks. In this case the MSEC equals the TSEC and common is specified for cryptomode.

[1] The official National Security Agency (NSA) abbreviation for JTIDS/Link 16 transmission security is TRANSEC. Another system uses the abbreviation TSEC. However, on many forms (e.g., connectivity matrix) is has been convenient for the JTIDS/Link 16 community to further shorten TRANSEC to TSEC.



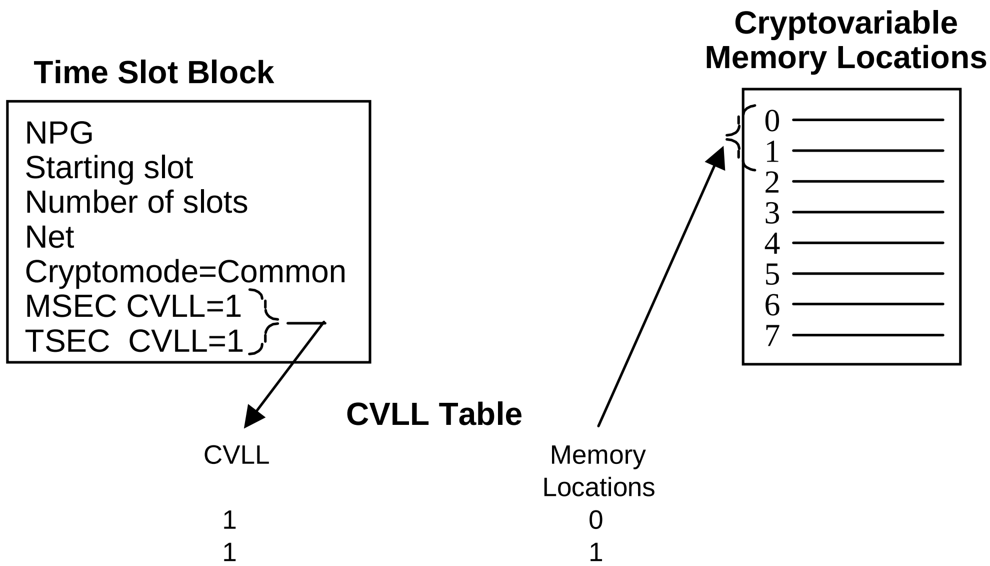
7.2-1 Cryptokey Utilization – Cryptovariable Logical Label

If we could use the cryptokey specified in a given time slot assignment for an entire mission, then we could simply specify the memory location for MSEC and TSEC in the time slot block. However, using the same encryption slot after slot, day in and day out would increase the vulnerability of the system. So the terminal changes the encryption sequence from slot to slot for each 24 hour period independent of cryptokey, and we change the cryptokey each 24 hour period, so that the same encryption sequence is never repeated.

Now we can't expect an operator to manually change cryptokey at 24:00 hours[2] each day. There would most certainly be a period of time during which the terminal would be without the new cryptokey. In addition, for some platforms such as fighters, the operator cannot physically load cryptokey when the platform is airborne, and it may be airborne when 24:00 hours occurs. So an automated approach for changing cryptokey was developed. It's implemented by using the memory locations in pairs, one for today and the other for tomorrow. Today's cryptokey is loaded into one memory location and tomorrow's cryptokey is loaded into the other. The terminal starts with the memory location holding today's cryptokey and when tomorrow comes, it automatically destroys today's cryptokey and begins to use tomorrow's. This process is termed crypto rollover.

The way in which this is implemented requires the definition of a new initialization parameter, the cryptovariable logical label (CVLL). The CVLL is simply a numeric label between 1 and 127. Then we assign a CVLL to the MSEC and a CVLL to the TSEC in each time slot assignment rather than the memory location of the cryptokey. Normally, we start with CVLL=1 as shown in the figure. Then we add a table of initialization data associating the CVLL with a memory location pair.

[2] Network time. This will normally be Zulu time, but other time bases can be used (e.g., local time).



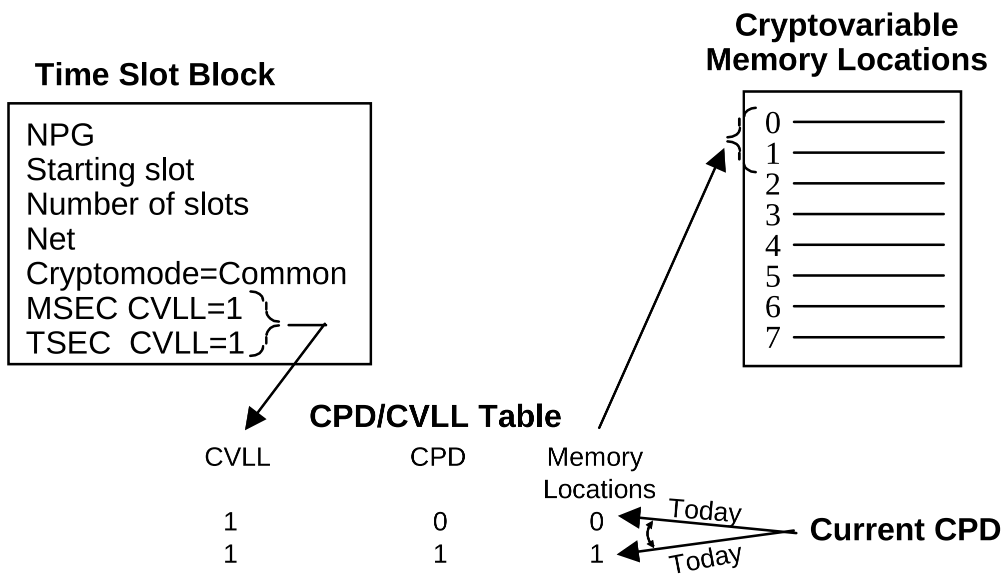
7.2-2 Cryptokey Utilization – Cryptovariable Logical Label

If we only had to operate through one rollover, we could operate just as illustrated above, always loading today's cryptokey in the first location and rolling over to tomorrow's cryptokey in the second location. However, there are some platforms which will wish to continuously operate in a Link 16 network day in and day out. They would like to begin operations by loading today's cryptokey and tomorrow's cryptokey. Then each day, after rollover, the key fill operator would load only tomorrow's cryptokey[3], preferably while today's is in use[4]. With this procedure, the key fill operator would load tomorrow's key into memory locations 0 and 1 alternately, as the days go by. So a standard procedure for determining in which location tomorrow's cryptokey should be loaded on any given day was required.

---

[3] At rollover, the line of the CVLL table associating a CVLL with the memory location for which the cryptokey is destroyed is also destroyed. So, if loading tomorrow's cryptokey after a rollover, it is also necessary to reinitialize the terminal to restore the line of the CVLL table associated with tomorrow's cryptokey.

[4] As it turned out, the JTIDS Class 2 terminal must be placed in Standby (i.e., out of network operation using battery power) in order to load cryptokey. So, after rollover, it is not possible to load tomorrow's cryptokey while today's is being used to maintain continuous operation in the network. However, the MIDS LVT will permit cryptokey fill and reinitialization while the terminal is operating in the network. So it will permit continuous operation in the network as originally envisioned when this standard procedure was devised.



7.3 Cryptokey Utilization – Cryptoperiod Designator

The standard procedure requires the definition of another initialization parameter termed the cryptoperiod designator (CPD). The CVLL table is expanded to include the CPD. By convention, a CPD of 0 is assigned to the even memory locations (0, 2, 4, 6) and a CPD of 1 is associated with the odd memory locations (1, 3, 5, 7). Then date is associated with CPD. The convention calls for the CPD to be 0 on 1 January 1985 and thereafter to alternate each day. Thus, by knowing today's date one can determine the CPD for today and, therefore, in which of the two locations to load today's cryptokey to get started. Determining the CPD is done with a CPD prediction table as included on the next page. One can also determine where to load tomorrow's cryptokey to maintain continuous operations.

The last initialization parameter which must be defined is "current CPD". After loading the terminal appropriately, the current CPD instructs the terminal which memory location to start with. Current CPD can also be determined using the CPD prediction table. For the E-3 the current CPD is entered via the Control Monitor Set (CMS)[5]. For the Rivet Joint, the data link operator will change the current CPD in the host processor stored initialization data set and then reinitialize the terminal[6].

Some platforms support the entry of date, rather than current CPD, and compute the current CPD for the operator. The F-15 is an example of such a platform. Date is entered at the AFMSS which computes current CPD and includes both the current CPD and the date in the initialization load placed on the data transfer module (DTM). When the pilot loads the initialization data from the DTM the date is displayed. If it is not correct, he can enter the correct date and the terminal will correct the current CPD for him, automatically.

---

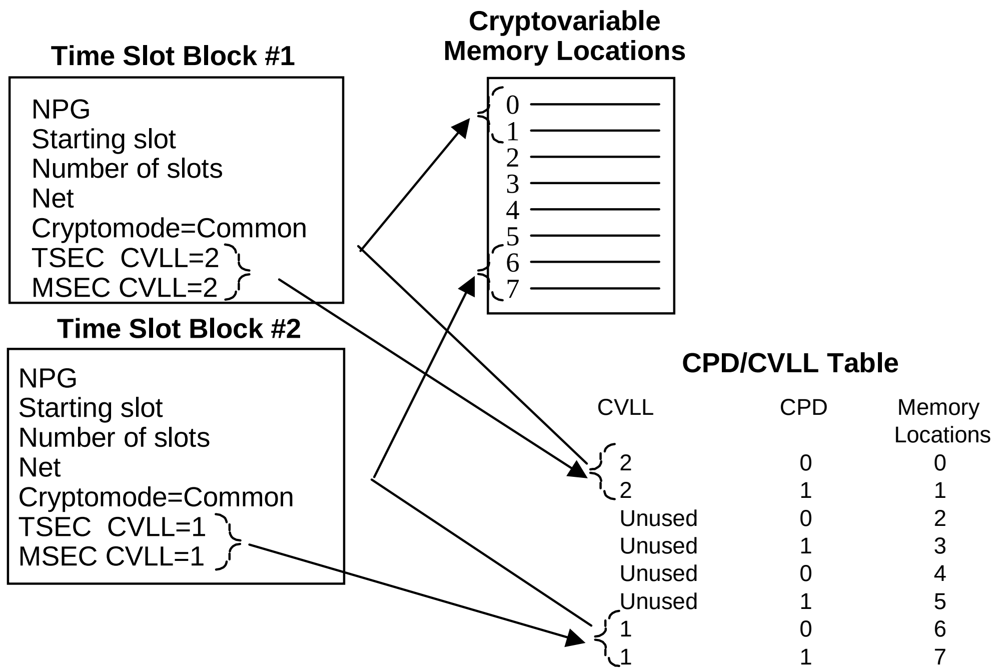
[5] Note that after having loaded key and initialized the terminal including current CPD, if the technician finds the current CPD is in error and corrects it, he must follow that with a command to the terminal to restart using current data otherwise the terminal will not make the linkage between the new current CPD and its impact on the memory locations to be used. The command is labeled "RESTART CURR DATA".

[6] Reinitialization requires placing the terminal in Standby then returning it to On before initialization.

	CPD Prediction Table					
Leap Year	2000, 2008, 2016, 2024, 2032, 2040			1996, 2004, 2012, 2020, 2028, 2036		
	Month	If Day is:		Month	If Day is:	
		ODD	EVEN		ODD	EVEN
	JAN	0	1	JAN	1	0
	FEB	1	0	FEB	0	1
	MAR	0	1	MAR	1	0
	APR	1	0	APR	0	1
	MAY	1	0	MAY	0	1
	JUN	0	1	JUN	1	0
	JUL	0	1	JUL	1	0
	AUG	1	0	AUG	0	1
	SEP	0	1	SEP	1	0
	OCT	0	1	OCT	1	0
	NOV	1	0	NOV	0	1
	DEC	1	0	DEC	0	1
Non-Leap Year	1997, 1999, 2002, 2005, 2007, 2010, 2013, 2015, 2018, 2021, 2023, 2026, 2029, 2031, 2034, 2037, 2039			1995, 1998, 2001, 2003, 2006, 2009, 2011, 2014, 2017, 2019, 2022, 2025, 2027, 2030, 2033, 2035, 2038		
	Month	If Day is:		Month	If Day is:	
		ODD	EVEN		ODD	EVEN
	JAN	1	0	JAN	0	1
	FEB	0	1	FEB	1	0
	MAR	0	1	MAR	1	0
	APR	1	0	APR	0	1
	MAY	1	0	MAY	0	1
	JUN	0	1	JUN	1	0
	JUL	0	1	JUL	1	0
	AUG	1	0	AUG	0	1
	SEP	0	1	SEP	1	0
	OCT	0	1	OCT	1	0
	NOV	1	0	NOV	0	1
	DEC	1	0	DEC	0	1

7.4 Cryptokey Utilization – CPD Prediction Table

The CPD prediction table is used to determine the CPD given the date. The appropriate year is found in the appropriate header. Then, for that year and under that header, the month is found. The CPD is then determined based on the date being odd or even. For example, the CPD for 17 November 1999 is 1.



COMSEC CROSS REFERENCE TABLE

		CRYPTOVARIABLE LOCATIONS			
ROW	**PARTICIPANT/# Un_itS**	**0/1**	**2/3**	**4/5**	**6/7**
1	E3(1)				1
2	CRC(1)				1
3	CRC(2)				1
4	F15(1.1.1)	2			1

7.5 Cryptokey Utilization – COMSEC Cross Reference Table

Some networks employ more than one cryptokey. One cryptokey is used for most information exchanges (i.e., NPGs), but a different cryptokey is used for some specific exchanges. For example, in a network combining allies, most exchanges could be using an allied cryptokey while some specific exchanges might be using a US-only cryptokey. Therefore, we cannot count on simply using one cryptokey and memory locations 0 and 1. When a network is designed, the CVLLs are assigned to the NPGs and are associated with memory location pairs. Then, when the network description and initialization data is distributed, the association of CVLL and memory location pairs is part of the initialization data and the description. The association in the description is called the COMSEC cross reference table and is illustrated in the above figure. In the illustration all network participants except the F-15s will only use CVLL 1, and the associated cryptokey will be loaded into memory locations 6 and 7. The F-15s will use CVLL 1 and an additional CVLL 2. The cryptokey associated with CVLL 2 will be loaded into memory locations 0 and 1. The Air Force currently uses locations 6 & 7 for main information exchanges with CVLL 1, and locations 0 & 1 for any segregated exchanges with CVLL 2. It is expected that this will change to using locations 0 & 1, and 2 & 3, respectively, as do most other services/nations.

OPTASKLINK MESSAGE

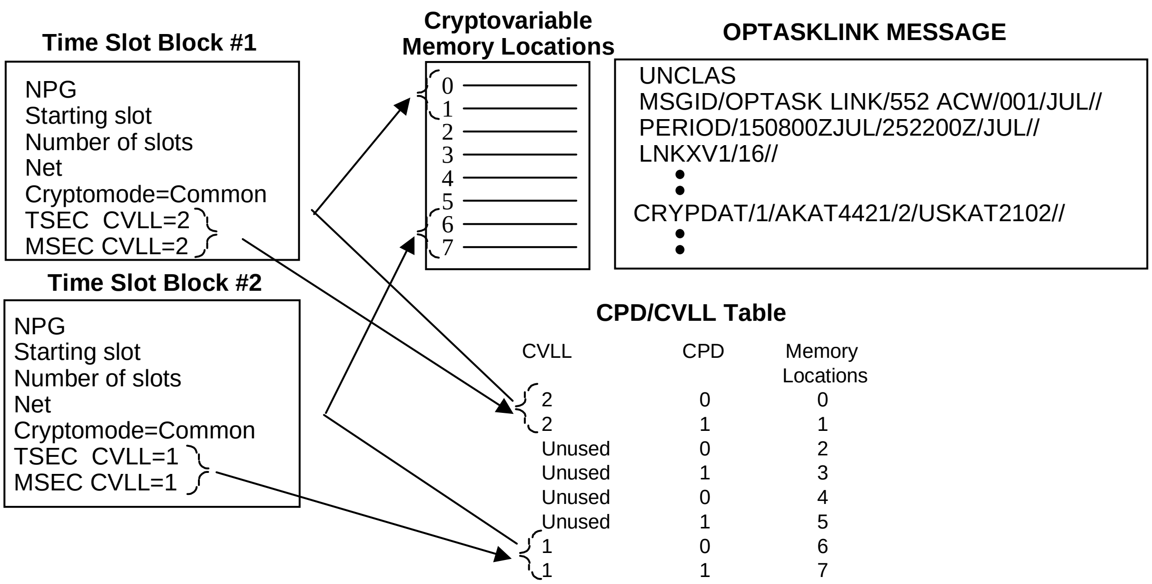
```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200Z/JUL//
LNKXV1/16//
    •
    •
CRYPDAT/1/AKAT4421/2/USKAT2102//
    •
    •
```

7.6 Cryptokey Utilization – CRYPDAT

A network is designed in terms of CVLLs. When the network is put into operation by a network manager[7], he/she[8] must associate a real cryptokey with each CVLL in the network. The real cryptokey will have a key short title (e.g., AKAT4421[9]). The cryptokey associated with each short title will be published in an edition for each month. Each edition will include a segment for each day of the month. The association of cryptokey short title with CVLL is distributed to all participating units via the OPTASK LINK message. The item in the message is termed CRYPDAT.

The CRYPDAT item is illustrated in the figure. It consists of a CVLL followed by the associated short title and the pairing is repeated to associate all CVLLs used in the network with a key short title. In the illustration the network uses two cryptokeys, and CVLL 1 is associated with AKAT4421, e.g., an allied cryptokey, while CVLL 2 is associated with USKAT2102, e.g., a US-only cryptokey.

[7] Including the wing/unit manager acting as network manager for training networks
[8] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.
[9] These are fictional titles for illustrative purposes only



COMSEC CROSS REFERENCE TABLE

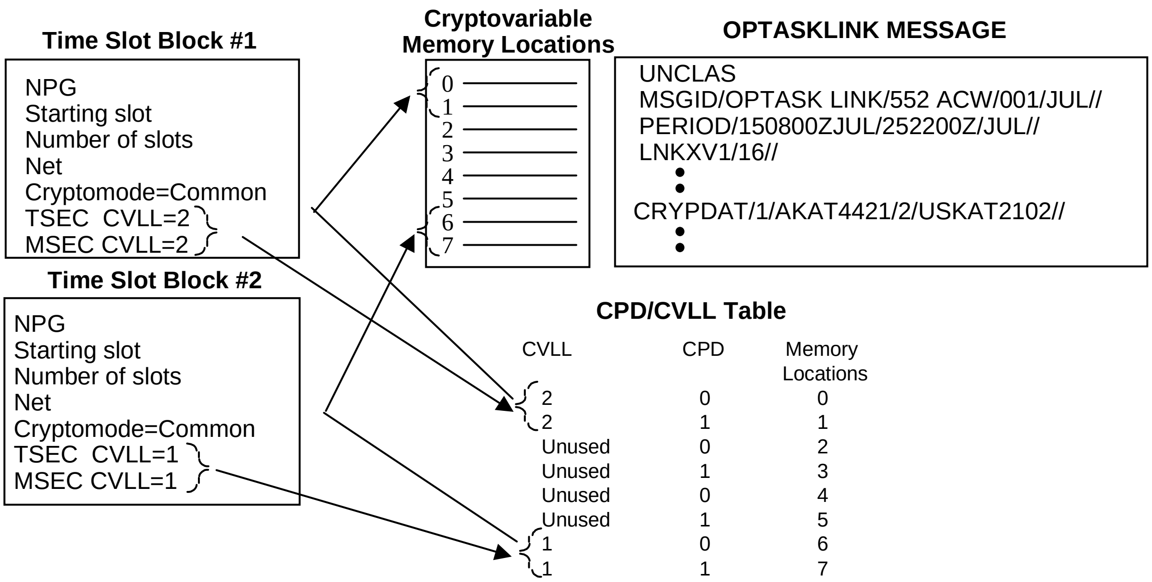
ROW	PARTICIPANT/# Un_itS	CRYPTOVARIABLE LOCATIONS 0/1	2/3	4/5	6/7
1	E3(1)				1
2	CRC(1)				1
3	CRC(2)				1
4	F15(1.1.1)	2			1

7.7-1 Cryptokey Utilization – An Example

A network has been designed. It employs two cryptokeys, one, associated with CVLL 1, for general use by all participants including allies (perhaps a UK E-3), and the other, associated with CVLL 2, for use only by F-15s for some specific exchanges. All time slot blocks will be assigned using the common variable mode. Segregated time slot blocks assigned to the F-15s will be of the form shown in time slot block #1 at the top of the figure. General use time slots blocks will be of the form shown in time slot block #2 below. The CPD/CVLL table for the F-15s is shown in the figure. This will be included in the F-15 initialization data. The CPD/CVLL table for the other participants will have the first two lines unused, as are the mid four lines for all platforms.

Now suppose that on 15 July 2001 we are putting the network into operation. The communication operators will load the initialization data for their respective platform into their terminal, and it will contain time slot assignments specifying the intended encryption via CVLL, and the CPD/CVLL table associating CVLL with cryptokey memory location pairs. The platform communication operator (or a key fill operator acting under his direction) must load the memory locations with the correct cryptokey, and specify the current CPD directing the terminal which memory location to start with.

The network manager will decide which real cryptokey to use for each CVLL and specify it in the OPTASK LINK via the CRYPDAT item. This is illustrated in the figure



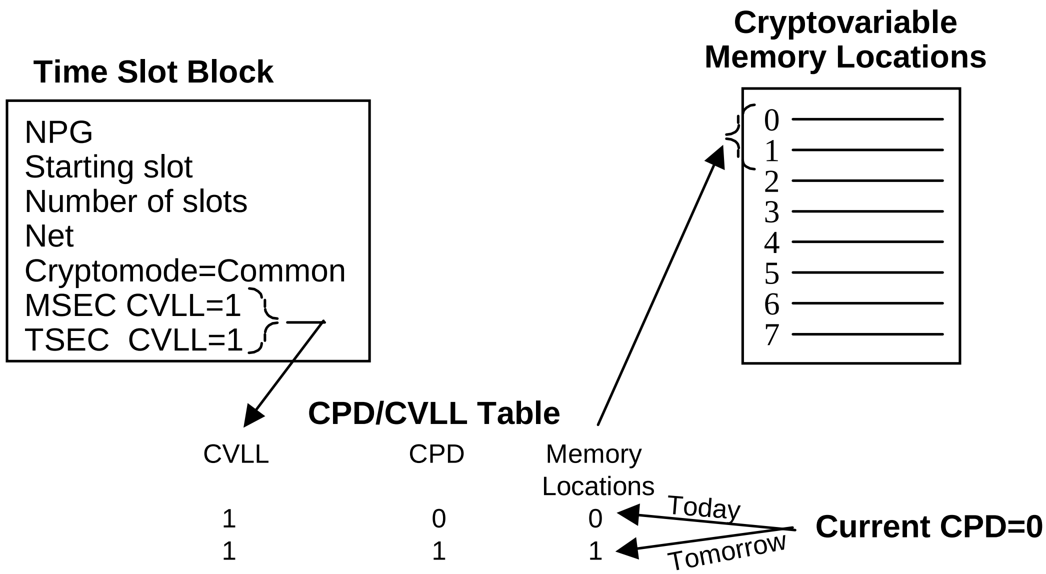
COMSEC CROSS REFERENCE TABLE

		CRYPTOVARIABLE LOCATIONS			
ROW	**PARTICIPANT/# Un_itS**	**0/1**	**2/3**	**4/5**	**6/7**
1	E3(1)				1
2	CRC(1)				1
3	CRC(2)				1
4	F15(1.1.1)	2			1

7.7-2 Cryptokey Utilization – An Example

and associates AKAT4421 with CVLL 1 and USKAT2102 with CVLL 2. The communication operator will refer to the COMSEC cross reference table to determine in
which key pair each cryptokey must be loaded. For the F-15s, they will load AKAT4421 in locations 6 and 7, and USKAT2102 in locations 0 and 1. All other platforms will load AKAT4421 in locations 6 and 7 and will not be provided USKAT2102. The operator will, by convention, use the edition associated with July, and segment 15, for July 15, and 16 for July 16. He will use today's date, 15 July 2001, to look up the current CPD via the CPD prediction table. The current CPD is 1. This means that, for the F-15s, he will fill locations 1 and 7 with today's cryptokey. Segment 15 of USKAT2102 will be loaded into location 1 and segment 15 of AKAT4421 will be loaded into location 7. He will fill locations 0 and 6 with tomorrow's cryptokey, segment 16 of USKAT2102 for location 0 and segment 16 of AKAT4421 for location 6. For the F-15s, key fill is accomplished by a maintenance technician as directed by the unit manager. For the other platforms, segment 15 of AKAT4421 will be loaded into location 7 and segment 16 of AKAT4421 will be loaded into location 6 directly by the communications operator.

The operator must now initialize the current CPD of 1. This is done directly for the E-3 and RJ, and will instruct those terminals to start up with the cryptokey in location 7. In the case of the F-15 this is done automatically by having the pilot specify 15 July 01 as the date on which he will enter the network.



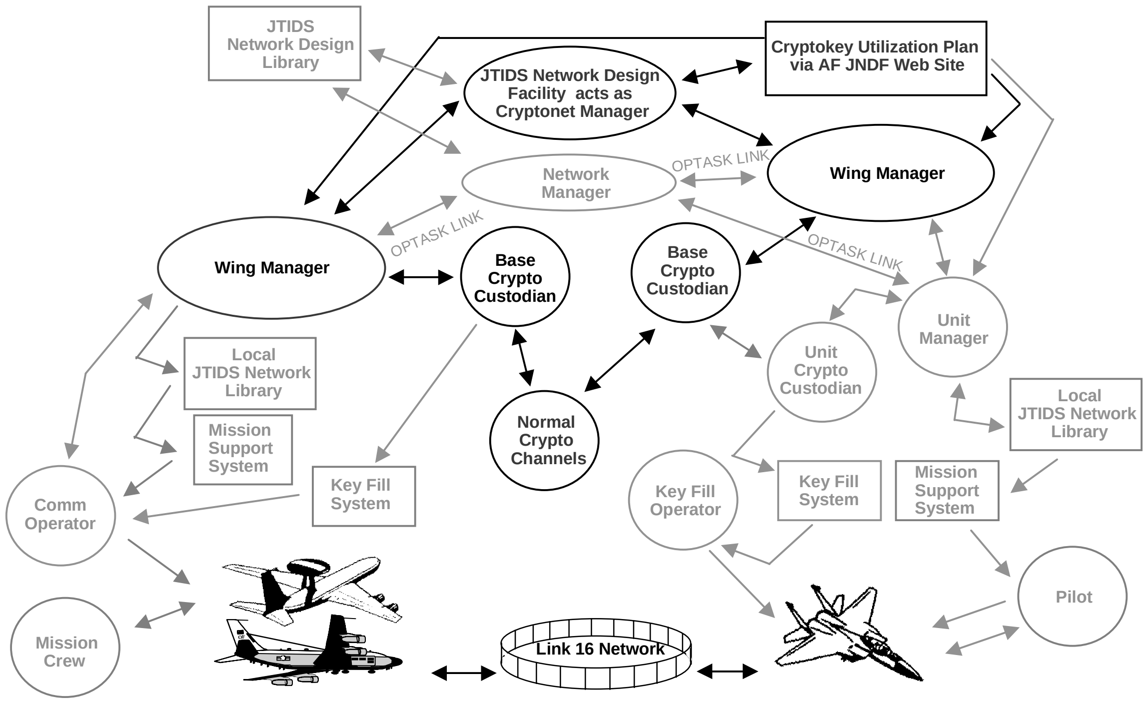
7.8 Cryptokey Utilization – An Alternative Key Fill Approach

The international convention for Link 16 cryptokey fill is to alternate CPD from day to day. This convention was established to support continuous operation in a Link 16 network day in and day out. It provides the cryptokey fill operator for the platform with a means to always know in which memory location to load tomorrow's cryptokey for continuous operations, and in which memory location to load today's cryptokey to get started.

Some airborne platforms do not need to operate in a Link 16 network day in and day out and so will be required to operate through only one rollover. Some such Air Force platforms have developed their own procedures which do not require the use of the CPD/CVLL table and are still compatible with the internationally agreed to convention. This is done by always entering a current CPD of zero, loading today's cryptokey into the even memory locations (i.e., locations 0, 2, 4 and 6) and tomorrow's cryptokey into the odd memory locations (i.e., 1, 3, 5 and 7). With this convention today's cryptokey in locations 0, 2, 4 and 6 always roll over to tomorrow's cryptokey in locations 1, 3, 5 and 7, respectively.

However, there are dangers in breaking with the internationally agreed to convention[10]. First, it falls to the communication operators of the platform in question to be knowledgeable of both approaches so they can intelligently coordinate on cryptokey fill debugging with other platforms, services and nations. This is a significant burden since cryptokey fill procedures are complex enough if everyone is using the same approach. Second, communication operators can (and have) confuse the two approaches[11] thus failing to properly synchronize with the network. Therefore, the Air Force JTIDS Network Design Facility (AF JNDF) does not endorse this alternative approach and urges all Air Force platforms to use the internationally agreed to approach.

[10] With the agreement explicitly including the US Air Force
[11] For example, they might load today's cryptokey into the even locations and tomorrow's cryptokey into the odd locations, but then look up the current CPD in the CPD/CVLL prediction table and enter it. This would result in the platform using the correct cryptokey only half the time, when the current CPD happened to be 0. However, it would always match the cyptokey of another platform making the same mistake. The 50% failure with platforms operating correctly could be a particularly difficult problem to diagnose.



7.9 Cryptokey Utilization – Cryptonet Management

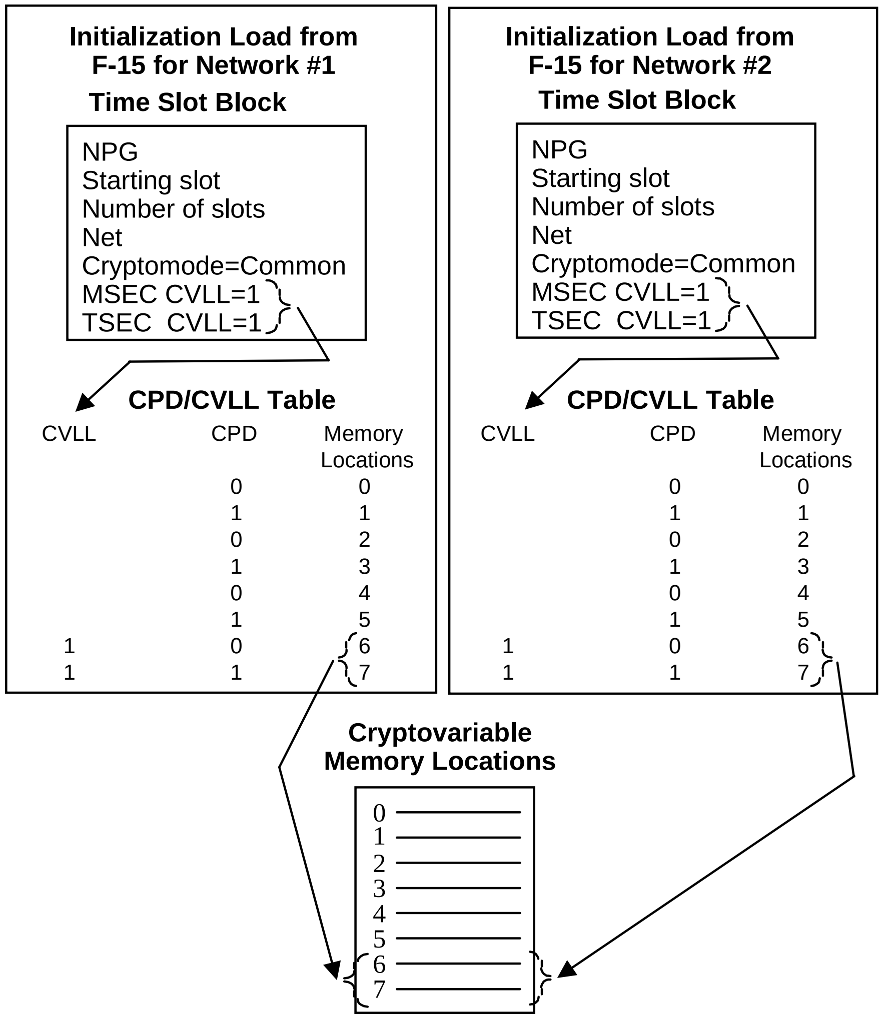
To load the required cryptokey, the communication operator (or key fill operator) must draw the cryptokey from the base or unit cryptocustodian. A procedure is required to ensure that the cryptokey is there. This procedure is called cryptonet management.

First, it is necessary to plan what keys will be required to support all of the envisioned networks. For the Air Force, the office responsible for this is the Air Force JTIDS Network Design Facility (AF JNDF). When acting in this capacity the AF JNDF is called the Air Force Cryptonet Manager. For Air Force cryptokeys, this planning can be done by the AF JNDF alone. However, for joint and allied operations, the AF JNDF must work with the cryptonet managers of the other services and nations. The result is a cryptokey utilization plan. For Air Force users, this plan is posted on the AF JNDF web site[12].

The cryptokey utilization plan will instruct wing managers what cryptokeys they should order via normal cryptochannels. Access to Air Force cryptokeys is controlled by the AF JNDF. This is not the case for joint and allied keys, and the controlling agency for such keys will be part of the cryptokey utilization plan.

The cryptokey utilization plan also enables a network manager[13] to select cryptokeys to use for his network. The plan will tell him which cryptokeys are available to the platforms which will be participating.

[12] Reached via http://totn.do.langley.af.mil/ .
[13] Including the wing/unit manager acting as network manager for training networks

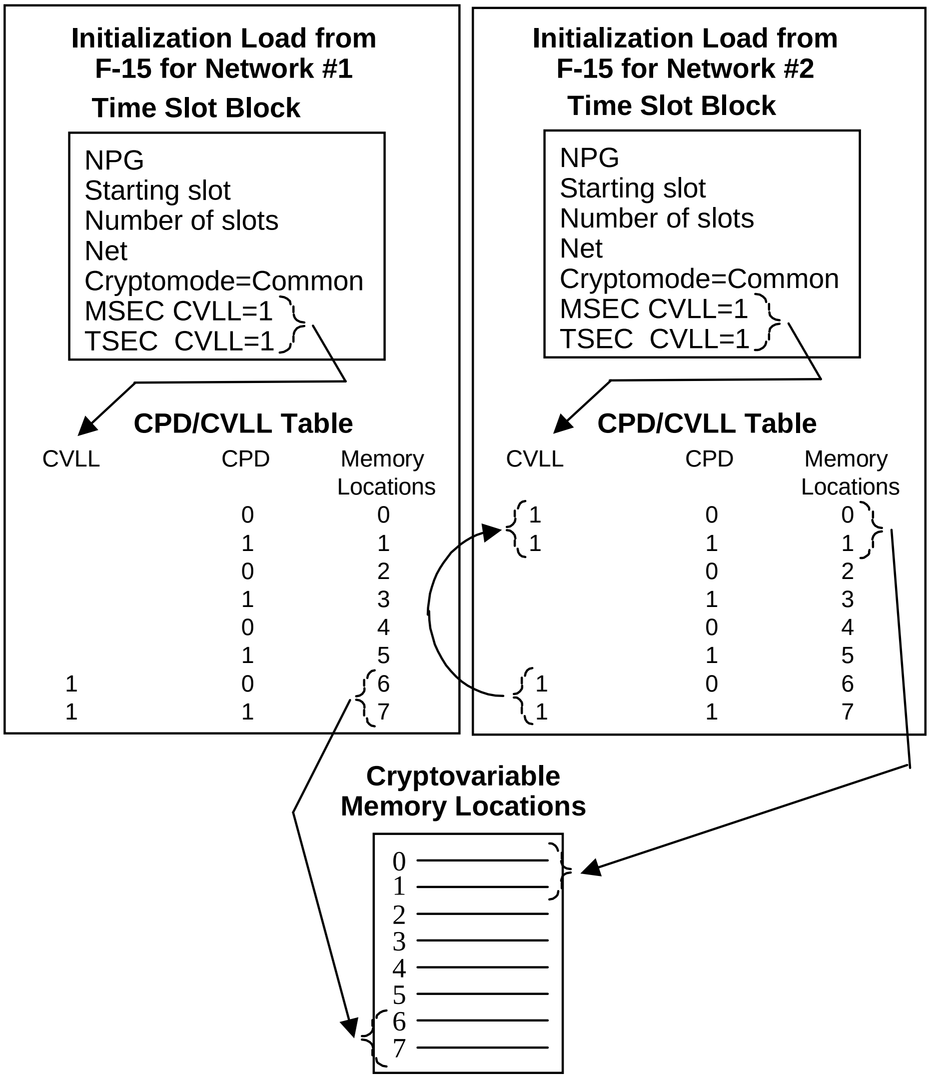


7.10-1 Cryptokey Utilization – The F-15 Cryptostep Capability

At the AFMSS the F-15 has the capability to place two initialization data sets on the data transfer module (DTM). The pilot can then select either set to load into the terminal from the cockpit. The two sets are typically from two different Link 16 networks and permit the F-15s to operate in either network without returning to the AFMSS. The CPD/CVLL table for both networks typically look alike. For illustrative purposes we show only the main cryptokey identified by a CVLL=1 associated with memory locations 6 and 7. Having the same CPD/CVLL table works fine as long as both networks utilize the same real cryptokey, e.g., AKAT 4421. However, it is not uncommon for two networks operating in the same geographic area to operate on different real cryptokeys. In this circumstance, since only one real cryptokey can be loaded into locations 6 and 7, the F-15 cannot operate in either network. It can only have the real cryptokey for one of them loaded into locations 6 and 7.

To eliminate this restriction, the AFMSS provides what is termed a "cryptostep" capability. The first initialization data set is placed on the DTM in its designed state as illustrated in the figure for network #1. Then, after the pilot[14] elects to add a second initialization data set, but before it is placed on the DTM, the pilot is given the option to

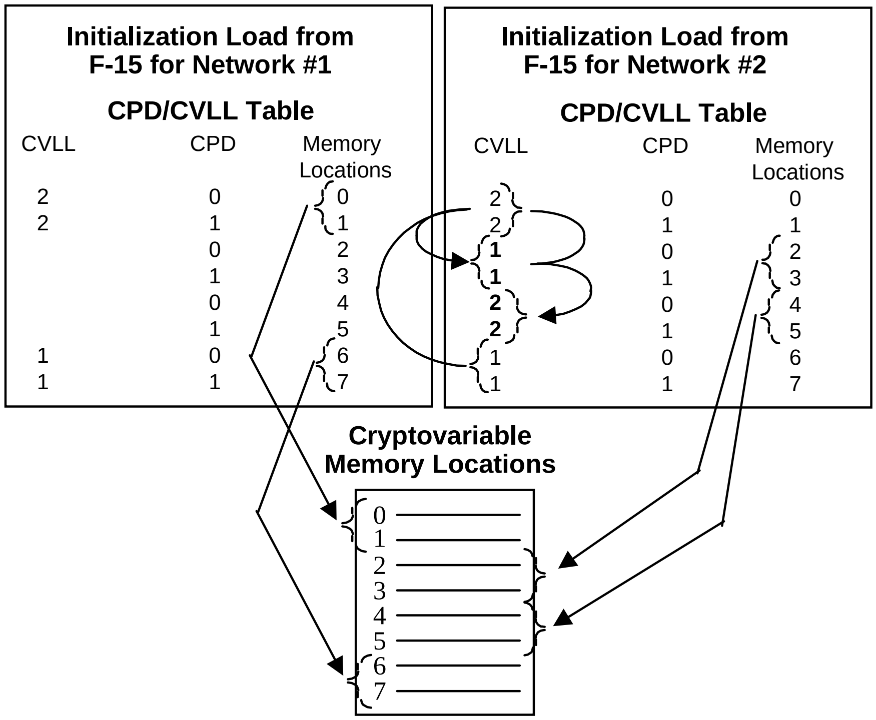
[14] It may actually be the unit manager preparing the DTMs for the squadron.



7.10-2 Cryptokey Utilization – The F-15 Cryptostep Capability

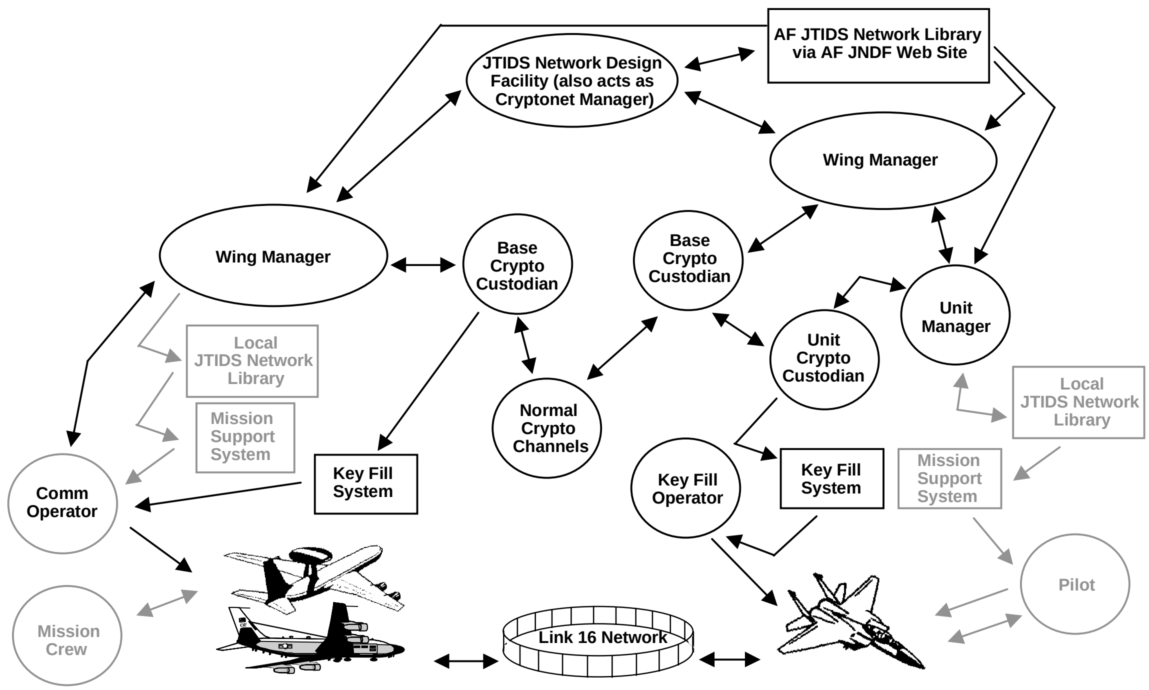
"step" the CPD/CVLL table in the second set shown for network #2. With each step, the AFMSS alters the CPD/CVLL table by stepping the CVLLs , pair by pair.

The step as applied to the initialization data set for network #2 is illustrated in the figure for which locations 6 and 7 are stepped to locations 0 and 1. Similarly, the CVLL for locations 0 and 1 would be stepped to 2 and 3; the CVLL for locations 2 and 3 would be stepped to locations 4 and 5; and the CVLL for locations 4 and 5 would be stepped to locations 6 and 7. Notice, that with the illustrated step, the cryptokey fill operator now loads the cryptokey for network #2 associated with CVLL 1 in locations 0 and 1, not locations 6 and 7. The pilot can now operate in both networks simply by making an initialization data set change from the cockpit.



7.10-3 Cryptokey Utilization – The F-15 Cryptostep Capability

If the F-15 is operating in networks in which it is using two cryptokeys, the pilot will have to step the CPD/CVLL table twice in the second data set. This is illustrated in the figure. The real cryptokeys associated with CVLL 1 and CVLL 2 will be loaded into locations 6 and 7, and 0 and 1, respectively, for the first network. However, for the second network, the real cryptokeys associated with CVLL 1 and CVLL 2 will be loaded into locations 2 and 3, and 4 and 5, respectively. This will be the case even if the real cryptokey for the segregated exchanges of the two networks associated with CVLL 2 is the same. It simply means that the same cryptokey will have to be loaded into two locations.



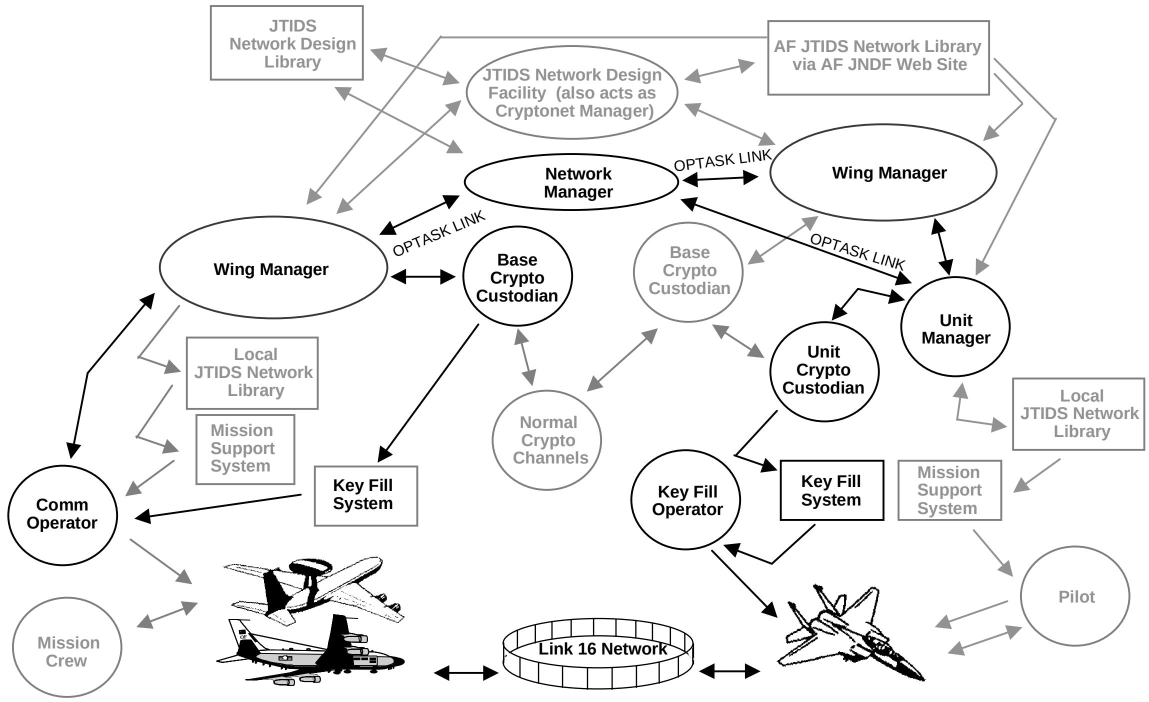
7.11 Cryptokey Utilization – In Garrison Cryptokey Operations

The wing manager in garrison responsibilities divide into preparing the wing for operations and acting as network manager for daily training. For the first responsibility the wing manager should consult the cryptokey utilization plan on the AF JNDF web site and order the cryptokey which is indicated for his platforms via the base cryptocustodian and normal cryptochannels. At fighter wings, the wing and unit managers should ensure that adequate cryptokey is drawn from wing accounts and held at unit level for daily use. At C^2 wings all cryptokey is normally held at wing level.

When acting as network manager for daily training, the wing or unit manager should make reference to the cryptokey utilization plan and the cross reference table of the network which is to be operated and determine which short titles to associate with the required CVLLs. This association must be sent to the network participants, preferably[15] using the CRYPDAT element of the OPTASK LINK for the network. An example OPTASK LINK message is at the end of this section. For simple daily training in which the same network may be used day-in and day-out, it is simplest to establish a standing key fill procedure. However, the wing manager should ensure that adequate training for deployed operations in which other than standing key fill procedures are required is accomplished.

The wing manager's responsibilities regarding his platforms when operating in a locally managed network are the same as when his platforms are operating in a deployed network externally managed, and this is discussed in the next subsection.

[15] Less formal means has and is being used. However, it is critical that Air Force operators learn to read and use the OPTASK LINK message since it is the operational means agreed to by the US and her allies. Therefore, wing and unit managers are encouraged to use the OPTASK LINK for daily training.



7.12 Cryptokey Utilization – Deployed Cryptokey Operations

Information regarding the cryptokey required by platforms participating in a network will come to the platform operators via their wing/unit manager. Normally this will be via the OPTASK LINK message[16]. <u>It is the responsibility of the wing/unit manager to ensure that cryptokey fill is performed in accordance with the OPTASK LINK message and the network cross reference table contained in the associated network description in his local JTIDS network library</u>. <u>The wing/unit manager must ensure that his cryptokey fill operators have sufficient information to load the cryptokey in the correct terminal memory locations and to select the correct location with which to begin operations (i.e., choose the correct current CPD)</u>.

As with other aspects of the Link 16 system, <u>the wing/unit manager should be thoroughly familiar with the theory of cryptokey utilization as described in this document and act as the first line of technical support to his operators regarding cryptokey utilization</u>.

Improper cryptokey utilization is one of the primary causes of unsuccessful Link 16 operations including the use of the wrong short title, loading cryptokey into the wrong KGV-8 memory locations and selecting the wrong starting location (i.e., improper date or current CPD).

[16] However, for daily training, standing cryptokey utilization procedures may be used.

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UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

7.13 Cryptokey Utilization – OPTASK LINK

In the OPTASK LINK[17] message the CRYPDAT element is used to associate CVLL with key short title. In the example, AKAT 4421 is associated with CVLL 1 and USKAT 2102 is associated with CVLL 2.

[17] The OPTASK LINK message is explained throughout the document.

In garrison responsibilities in support of operations managed by personnel other than at wing:

3. Consult the cryptokey utilization plan on the AF JNDF web site and order the cryptokey which is indicated for wing platforms via the base cryptocustodian and normal cryptochannels. At fighter wings, the wing and unit managers should ensure that adequate cryptokey is drawn from wing accounts and held at unit level for daily use. Reference: para 7.11

4. Ensure that cryptokey fill is performed by wing operators in accordance with the OPTASK LINK message and the network cross reference table contained in the associated network description in his local JTIDS network library. Reference: para 7.11

5. Ensure that wing cryptokey fill operators have sufficient information to load the cryptokey in the correct terminal memory locations and to select the correct location with which to begin operations (i.e., choose the correct current CPD). Reference: para 7.12

Improper cryptokey utilization is one of the primary causes of unsuccessful Link 16 operations including the use of the wrong short title, loading cryptokey into the wrong KGV-8 memory locations and selecting the wrong starting location (i.e., improper date or current CPD)

Network manager responsibilities for daily training network operations:

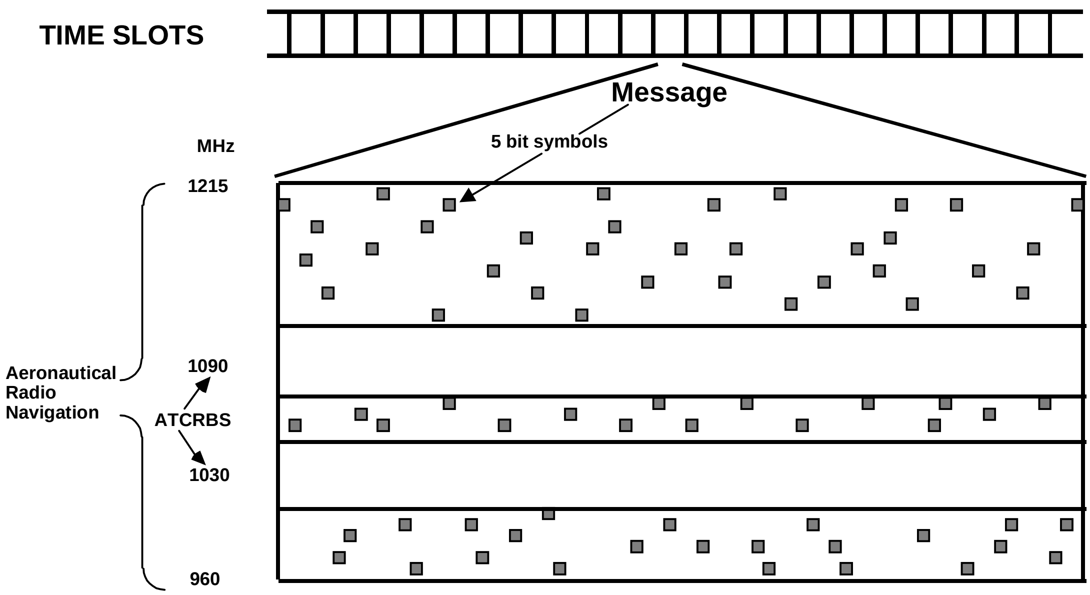
15. Make reference to the cryptokey utilization plan and the cross reference table of the network which is to be operated and determine which short titles to associate with the required CVLLs. This association must be sent to the network participants, preferably using the CRYPDAT element of the OPTASK LINK for the network. Reference: para 7.11

    a. For simple daily training in which the same network may be used day-in and day-out, it is simplest to establish a standing key fill procedure. However, the wing manager should ensure that adequate training for deployed operations in which other than standing key fill procedures are required is accomplished. Reference: para 7.11

7.14 Cryptokey Utilization – Wing/Unit Manager Checklist

This checklist is an extension of that started in the Network Management I section. It will be extended in subsequent sections and summarized in Network Management II.

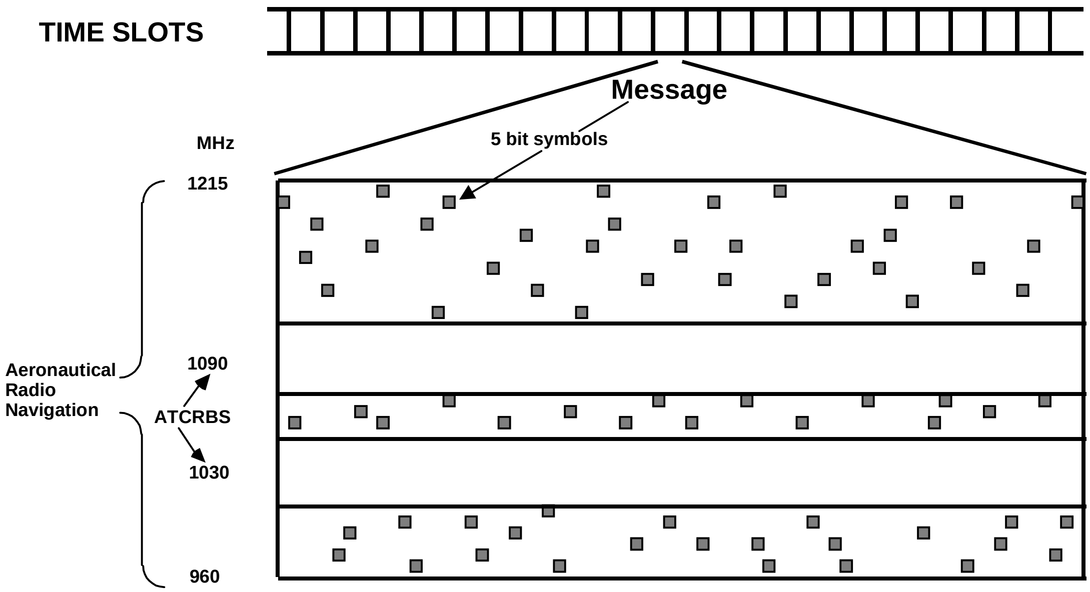
8.0 Frequency Management



8.1-1 Frequency Management – The Issue

To achieve the high data rates and jam resistance required of Link 16, a good deal of radio frequency spectrum (no less than 150 MHz) is required. To acquire this much bandwidth world wide, it is necessary to share the frequency spectrum with other systems. The portion of the spectrum selected was that reserved for aeronautical radionavigation within which lies the Air Traffic Control Radar Beacon System (ATCRBS)[1]. The specific navigation aids of concern are Distance Measuring Equipment (DME) and the Tactical Air Navigation (TACAN) system. Distance Measuring Equipment (DME) is a line-of-site beacon-based navigation system which provides slant range from the beacon. Very High Frequency (VHF) Omnidirectional Range (VOR) is a line-of-sight beacon-based navigation system which provides the user bearing relative to the beacon. VOR and DME can be used in conjunction for enroute air navigation. The Tactical Air Navigation (TACAN) system is the military equivalent of VOR and DME. DME beacons can be stand alone or part of a TACAN station. A station which is a combination of VOR and TACAN is termed a VORTAC.

[1] The ATCRBS is comprised of an interrogating radar (en route or terminal area) and a transponder installed on the aircraft. For the military, the Identification Friend or Foe (IFF) transponder acts as the ATCRBS transponder, with IFF mode 3 being equivalent to ATCRBS mode A.

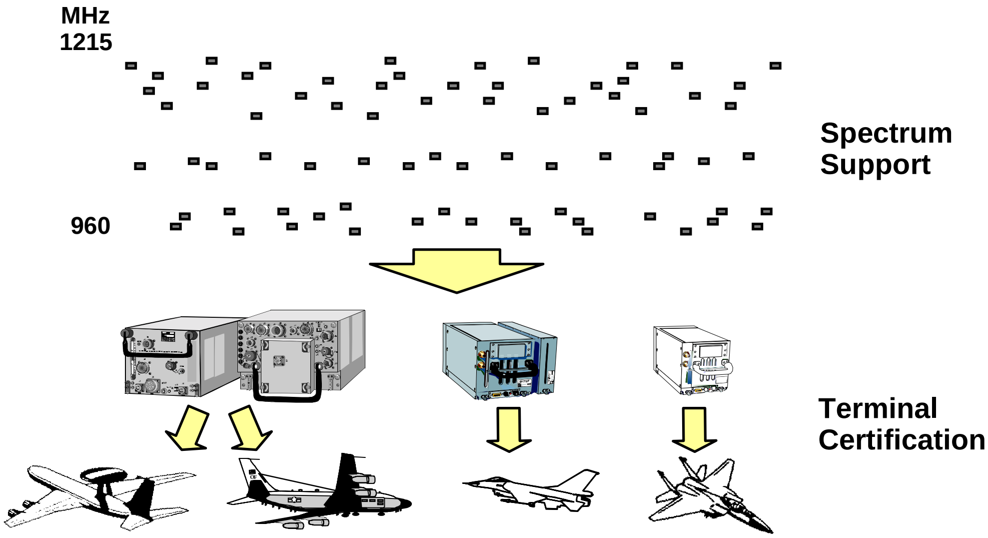


8.1-2 Frequency Management – The Issue

The aeronautical radionavigation band was selected because the required bandwidth is available, the TACAN/DME systems have strict performance standards facilitating compatibility and the two systems are designed to tolerate significant interference without disruption of service. The ATCRBS frequencies[2] ± 7 MHz are excluded from Link 16 use. Within the remaining portion of the band, 51 discrete frequencies are defined for JTIDS pulses and the pulse spacing selected to maximize compatibility with TACAN/DME. Despite this, the Federal Aviation Administration (FAA), which is particularly concerned with the aeronautical radionavigation band, has levied strict electromagnetic compatibility (EMC) constraints on use of the band for Link 16.

Adherence to these constraints is an essential part of Link 16 operation. They have been established under federal regulations and failure to comply with them can have legal consequences as well as threaten the ability for the Department of Defense (DOD) to utilize Link 16[3]. To provide guidance to their operators, the DOD has published two important documents, the JTIDS/MIDS Spectrum Users Guide and Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 6232.01A. <u>Wing managers should be familiar with these documents</u>. They are available on the AF JNDF web site[4]. This section draws information from those documents, illustrates its use and presents additional information peculiar to Air Force operations. However, frequency management requirements can and will change. Those changes will be described in updated versions of the two above cited documents, and be kept current on the AF JNDF web site. <u>The wing manager will be expected to keep up with evolving frequency management requirements by reference to those documents</u>.

[2] 1030 MHz for interrogation of the transponder by the radar and 1090 MHz for its reply
[3] This could involve further restrictions and, ultimately, refusal to permit the use of Link 16 at all.
[4] Reached via http://totn.do.langley.af.mil/ .



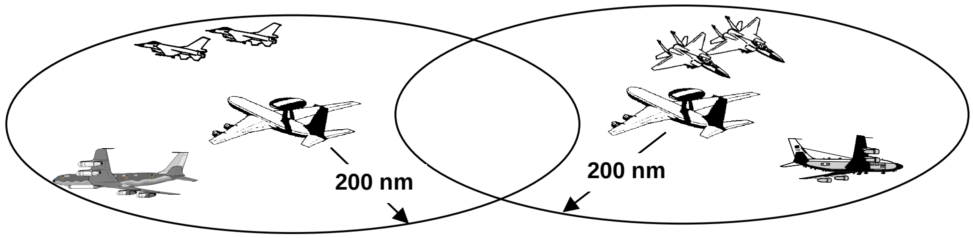
8.2 Frequency Management – Basic Responsibilities

Before the JTIDS and MIDS terminals could/can radiate, several items were/are required. First, before system development could go forward, the basic waveform which was planned had to be approved by the National Telecommunication and Information Administration (NTIA). This "spectrum support" was first granted in 1979[5] and was updated in 1991[6]. The spectrum support defines the basic waveform, a set of constraints on its use, and a set of requirements on the JTIDS/MIDS terminals.

Second, the Department of Defense had to demonstrate that each type of terminal radiated the approved waveform, satisfied the terminal requirements and could be operated in accordance with the system constraints. While preliminary approvals were granted earlier, formal approval for the use of the JTIDS Class 2 terminal was granted in 1998[7].

These two items were the responsibility of the developmental community and are not the responsibility of the individual Link 16 users. However, the next three important items are the responsibility of the Link 16 users. First, the approvals described above present constraints regarding how close to the radionavigation aids and ATCRBS radars the users can operate. Second, the users must be sure there is a frequency assignment under which they can operate. A frequency assignment is a specific authorization by the NTIA for specific platform types to operate the data link in specific areas during a specific period of time. Third, the users must coordinate the independent operation of Link 16 networks to ensure that their combined operation satisfies frequency utilization constraints. This latter task is termed frequency deconfliction. Within the Air Force, the wing manager[8] is responsible for ensuring that these three items are properly dealt with by the wing personnel. These responsibilities will be discussed in this section. However, this section will treat only operations within the US and her possessions (US&P). The wing manager should consult the Spectrum Users Guide regarding the operation of JTIDS/MIDS in other nations.

[5] NTIA letter Doc. 21167 dated 6 December, 1979
[6] NTIA letter Doc. 27439 dated 30 July 1991.
[7] NTIA letter dated 7 April 1998.
[8] Except at bases which have only one unit equipped with Link 16 the unit manager may be responsible



8.3 Frequency Management – TSDF and 100/50/20 Constraints

One of the operational constraints involves the rate at which Link 16 pulses can be transmitted in a given geographic area. Using the pulses, messages are transmitted in time slots in accordance with the packing limits for the associated Network Participation Group[9] (NPG). For standard double pulse and packed two single pulse the terminal transmits 258 pulses per time slot. For packed two double pulse and packed four (single pulse) the terminal transmits 444 pulses. The basic measure for Link 16 transmissions is termed transmit time slot duty factor (TSDF). TSDF is referenced to one net's worth of pulses when operating standard double pulse. This is 396288 pulses per 12-second frame[10]. When computing the TSDF of a particular platform operating in a Link 16 network, all assigned time slots must be counted whether or not the platform expects to actually use all assigned time slots on any given application[11]. For example, an E-3 assigned 1 slot/frame for PPLIs and 128 slots/frame for surveillance, all at packed two single pulse, would exhibit an 8.4%[12] TSDF even if it was operating in a training mission and would only utilize about half of its assigned surveillance slots.

For operations within the US&P, the constraints extend to platforms operating within 200 nm of the shoreline. The constraints are such that (i.) the sum total of all individual platform transmit TSDFs within 200 nm[13] of each and every Link 16 user must be less than or equal to 100%, (ii.) JTIDS Class 1 or Class 2 terminal equipped platforms can use no more than a 20% transmit TSDF, and (iii.) a Class 2 terminal equipped primary control/relay aircraft[14] can use up to a 50% transmit TSDF if it is at or above 18000 ft MSL and separated at least 3 nm from any other aircraft. Hence, the terminology 100/50/20 constraints.

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[9] A functional grouping of messages used for data link capacity allocation purposes, e.g., surveillance
[10] 1536 slots/frame times 258 pulses per slot.
[11] Voice assignments are an exception since they are under operator control and will only be counted if voice is to be used by the operators in the related operation.
[12] 128+1 slots/frame times 258 pulses per slot divided by 396288 pulses
[13] This may be reduced to 100 nm. Changes to this and other Link 16 frequency management requirements should be monitored by reference to the JTIDS/MIDS Spectrum User's Guide at the AF JNDF web site.
[14] Meaning large aircraft such as the E-3 and Rivet Joint, not currently fighters

JTIDS/MIDS Surface Distance (in nautical miles) Separation Requirements

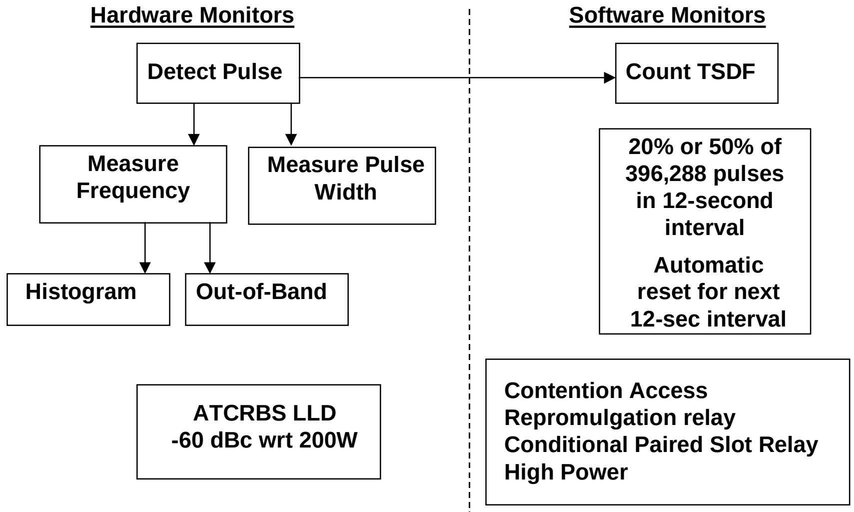
Platform	DME Beacons	TACAN Beacons	En Route ATCRBS	Terminal ATCRBS	En Route Mode S	Terminal Mode S
Rx[15], dBm	-33	-33	-20	-20	-22	-22
E-3	0.59	0.59	1.16	0.61	1.58	0.79
RC-135	0.44	0.44	0.86	0.46	1.17	0.59
F-15	0.52	0.52	1.02	0.54	1.39	0.70

8.4 Frequency Management – Separation Constraints

The separation restrictions on JTIDS/MIDS terminal utilization are given in the table above in nautical miles. The entries are drawn from a table in the JTIDS/MIDS Spectrum Users Guide for illustrative purposes. The wing manager should reference the actual table in the guide for the latest information and for additional platforms.

The received signal threshold (Rx) for each system applies to all platforms and the range interpretation is for the E-3, Rivet Joint (RC-135) and F-15. The constraints apply to the platforms only while they are on the ground (e.g., departing on a mission, returning from a mission or testing the system), not once they are airborne. Mode Select (Mode S) is a new capability of the ATCRBS and, as such, requires additional protection. There is an additional constraint not given in the table and that is the sum total of all individual ground based platform transmit TSDFs within 7 nm of a TACAN/DME beacon should not exceed 50%.

[15] Threshold of the received (Rx) JTIDS/MIDS signal at the input of the relevant receiver in dB relative to one milliwatt.



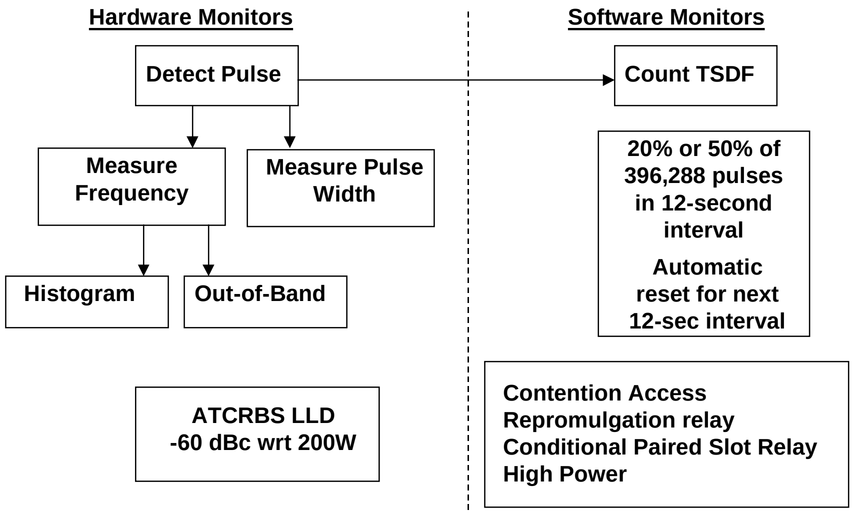
8.5-1 Frequency Management – Interference Protection Features

The approvals, both for the basic waveform and the terminals, require the terminals to provide interference protection features (IPF) to ensure that the terminals will maintain the proper waveform characteristics and operate within the transmission constraints. To call these features into effect there is an initialization parameter. The basic setting for normal operations within the US&P is 20% full protect. The features will first be described for that setting[16].

There are software and hardware monitors. The hardware monitors ensure the pulse width is as specified, stores the frequencies being used and checks to ensure that the transmissions over the 51 frequencies is distributed evenly, and monitors the adjacent frequency bands to ensure the transmitted power is not extending outside the permitted spectrum. There is also a low level detector (LLD) in the bands associated with the ATCRBS beacon. The detector ensures that the signal level in these bands does not exceed -60 dB with respect to a carrier level of 200 watts. If, while the terminal is operating, any of these checks fail, the terminal shuts down transmissions and will indicate “IPF fail” [17]. The operator can reset the IPF fail and the terminal will begin to operate again, but if the condition which caused the failure to occur persists the failure will again occur[18].

The software monitors check on the time slot assignments and initialization data as they are fed into the terminal. They will not permit (i.) assignments of the contention access transmission mode for other than RTTs[19] (ii.) use of repromulgation relay (an Army function), (iii.) use of conditional relay and (iv.) use of high power (i.e., 1000 watts). In addition, in the 20% full protect mode, the terminal will count the pulses being transmitted in each 12-second frame and, if they exceed a 20% transmit TSDF will shut down transmissions

[16] This is an IPF value of 0 for the JTIDS Class 2 and MIDS/FDL terminals and 3 for the MIDS/LVT. For some reason they’re different.
[17] Actually , an IPF fail takes two failures of a hardware check within a two hour period
[18] Experience indicates that the hardware monitors are quite sensitive and can occasionally trigger an IPF fail with a perfectly normal terminal.
[19] Round Trip Timing (RTT) messages for synchronization



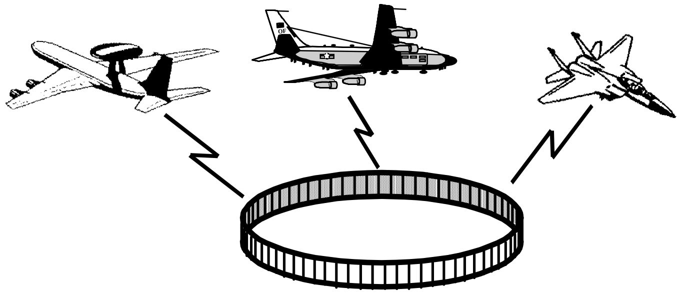
8.5-2 Frequency Management – Interference Protection Features

for the rest of the 12-second frame and declare an IPF fail. However, unlike the hardware checks, the 20% count fail will automatically reset itself every 12-second frame. Thus, it will permit transmissions, but limit them to a 20% TSDF. Once the situation is no longer occurring, the IPF fail indication will disappear. Networks are designed keeping assigned TSDFs and transmission modes within the constraints associated with the assigned IPF setting of the platform, so operators should never see IPF fails due to software monitors[20].

According to the 100/50/20 constraints, a primary control/relay aircraft can transmit with a 50% TSDF. To permit this, there is a 50% full protect IPF setting[21]. It exhibits the same features that the 20% full protect setting does except the pulse count is against a 50% TSDF.

There are two additional IPF settings. Exercise[22] drops the software checks but retains the hardware checks. This is for use when the features which the full protect features prohibit are to be used for test or to train with, and appropriate authorization has been granted. For example, the F-15s have been authorized to use exercise to employ the contention access transmission mode within military operations areas (MOAs). Combat[23] drops all checks. It is for use during wartime to eliminate the risk of experiencing an IPF fail at an inopportune time[24] or to permit the use of a terminal which is not working properly. Care should be taken when using the combat setting. A terminal which is not working properly could be adversely effecting the ATCRBS transponder performance and this is the mode 3 portion of the military IFF as well as the mode A portion of the civilian ATCRBS. <u>Combat is not authorized for use during normal peacetime operations.</u>

[20] To do so would indicate a faulty network design.
[21] This is an IPF value of 3 for the JTIDS Class 2 and MIDS/FDL terminals and 0 for the MIDS/LVT. For some reason they're different.
[22] This is an IPF value of 1 for all terminals.
[23] This is an IPF value of 2 for all terminals.
[24] The hardware monitors are very sensitive and can occasionally trip an IPF fail with a normal terminal. This requires an F-15 pilot to leave his tactical display and page to a menu with which to perform an IPF reset. While acceptable for training, this would not be desirable in a combat situation.



8.6-1 Frequency Management – Frequency Assignments

A platform cannot operate its JTIDS/MIDS terminal within 200 nm of the coastline of the US&P unless operating under a valid frequency assignment. The nature of frequency assignments and their use is changing, and so some background is warranted.

The F-15s began operations with JTIDS at Mt Home AFB. The initial frequency assignment sought was for Class 2 terminal equipped F-15s and Class 1 terminal equipped E-3s. The assignment request covered an area within 250 nm of the AFB and was intended for daily training without coordination for each use (termed uncoordinated operations). The Class 2 terminal equipped F-15 had not been approved for uncoordinated operations, and is still not so approved. The terminal approval currently held[25] does not include fighters since the FAA has concerns regarding the impact of JTIDS on the performance of the F-15's ATCRBS transponder. Work is underway to resolve those concerns for the Fighter Data Link (FDL) installation on the F-15. Without such approval, the local Mt Home assignment had several special constraints[26]. For example, while they could operate with a 100/50/20 constraint, and use the contention access transmission mode and 2.4 kbps voice within their MOAs, the F-15s could not transmit outside of their MOAs at all unless receiving positive primary radar control from the relevant Air Traffic Control (ATC) facility. In addition, if exceeding a 40/20[27] constraint or using voice outside of their MOAs, they were required to inform the FAA on a case-by-case basis. For cross-country flying, a separate frequency assignment was sought. This assignment traded off freedom of flight within the US&P for additional restrictions. The F-15 US&P assignment included one E-3 and limited the F-15 to a 2% transmit TSDF which compelled the use of the dedicated access transmission mode.

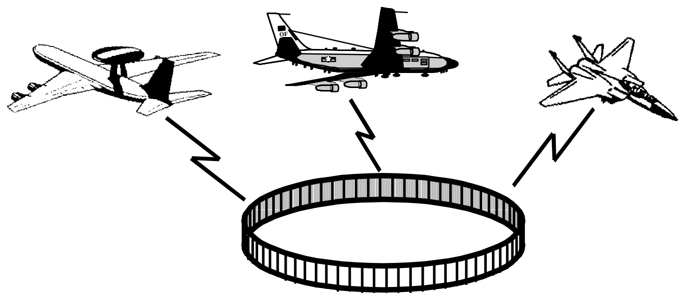
When the F-15s at Nellis AFB received Class 2 terminals, they too sought and received a local assignment like the Mt Home F-15s, and used the US&P assignment owned[28] by Mt Home AFB (i.e., the 366 WG) for cross country flying. Note that the Nellis F-15s did not require their own US&P assignment since there was already such an assignment in effect. Ownership of the frequency assignment is not a factor in determining who can use it. Only

[25] NTIA letter Doc. 27439 dated 30 July 1991.

[26] Since actual frequency assignments are changing, current assignments will not be treated in this document. Alternatively, representative past assignments and hypothesized assignments will be presented for illustrative purposes. Actual assignments will be reserved for the lecture which this document supports.

[27] The sum total of the TSDFs of F-15s operating outside of the MOAs (e.g., flying to and from the MOAs) could not exceed a 40% transmit TSDF.

[28] Ownership meaning that the Installation Frequency Manager listed in the assignment is the 366 WG frequency management officer.



8.6-2 Frequency Management – Frequency Assignments

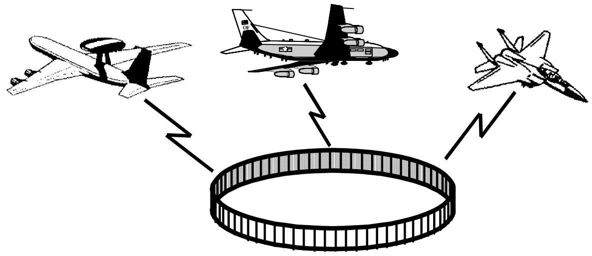
its suitability based on coverage area, platforms included, etc. This is an important concept that we will come back to.

The E-3 began operations with the Class 1 terminal. While the F-15s train in MOAs nearby their base, the E-3 trains in various locations around the US&P, so a local assignment is of marginal use to the E-3 for training. Therefore, the 522 ACW sought a US&P frequency assignment as its primary training assignment. A local assignment was secured, but for a ground test station located at Tinker AFB. The Rivet Joint requirements match those of the E-3. Both aircraft have notch filters which further reduce the transmission signal near the ATCRBS frequencies and are able to receive a 100/50/20 constraint for their assignment with no special restrictions. The F-15s, E-3 and Rivet Joint can work together at Mt Home AFB with the two C^2 platforms operating under their two US&P assignments, and F-15s operating under the local Mt Home assignment, and similarly at Nellis AFB with the F-15s operating under the local Nellis assignment. They can work together anywhere in the US&P under the three US&P assignments, although the F-15 link utilization will be more restricted.

Continuation of this approach for all new platforms as Link 16 is widely deployed would result in dozens, if not hundreds of frequency assignments. This would tend to bog down both the assignment acquisition and assignment management processes. Therefore, the goal is to minimize the number of assignments by including all platforms under a common US&P assignment[29], even if some of the platforms such as the F-15s require special restrictions. Local assignments would be reserved for special test requirements. The common frequency assignment would be "owned" by one installation frequency manager (IFM), but used widely by different types of platform operating from various bases. So while a platform must be operating under an approved frequency assignment in order to turn its terminal on, it need not be owned by the IFM associated with its wing[30].

The AF JNDF is following the evolution of the frequency assignment process from that in which each wing has one or more assignments to one in which there is one or at least a limited number of assignments. <u>Units planning to receive Link 16 should consult with the AF JNDF regarding their requirement for a locally owned frequency assignment</u>.

[29] Or as few assignments as are practical
[30] or other appropriate operational unit



8.7 Frequency Management – Frequency Assignment Request

When required, the frequency assignment will be originated by the local installation frequency manager (IFM). However, the wing manager will be responsible for establishing the operational requirements. The request will generally contain the requesting IFM, when the assignment is required, the duration of the assignment, the area of operation, participating platforms, the required TSDF, JTIDS/MIDS voice requirements, and a "stop buzzer" point of contact (POC) for the FAA to call if problems are perceived. While the normal TSDF constraints are 100/50/20, there is precedent for requesting additional capacity for limited periods for specific exercises. For example, the All Services Combat Id Evaluation Team (ASCIET) requests higher total TSDFs (e.g., 170/50/20) for their exercise each year.

The DOD has designated the Navy as the lead service for Link 16, and the cognizant Navy office is PMW-159, the Navy Program Manager for Advanced Tactical Data Links. PMW-159 is spearheading DOD's Link 16 spectrum certification and management programs. To support this activity, they have established a JTIDS/MIDS Spectrum Certification Integrated Product Team (Spectrum IPT). The Air Force JTIDS Network Design Activity (AF JNDF) participates in the Spectrum IPT and is cognizant of spectrum related issues. Therefore, the wing manager should consult with the AF JNDF to determine the availability of existing assignments, to obtain help in determining reasonable operational requirements for a required assignment and to gain assistance with the exact format of the assignment request.

The request will pass through normal Air Force frequency management channels to the Air Force Frequency Management Agency (AF FMA) and thence to the Navy frequency management agency, the Navy Electromagnetic Spectrum Center (NAVEMSCEN). NAVEMSCEN, as the frequency management agency for the lead service for Link 16, will perform all coordination with the NTIA and the FAA. Individual units or services are not authorized to contact the NTIA or FAA directly.

The format of the request as well as the format of the assignment when granted is of a special coded format. This format is described in detail in Air Force Manual 33-120 entitled Radio Frequency (RF) Spectrum Management. Wing managers should have a copy of this manual and be familiar enough with it that they can read the coded assignment under which they are operating. Wing managers are responsible for ensuring that the operators of their platforms are operating under and in accordance with a valid JTIDS frequency assignment. An annotated example of a frequency assignment is given in the next subsection. It does not represent a real assignment. It has been prepared solely to illustrate the format and why it is important for the wing manager to be familiar with the entire format.

8.8-1 Frequency Management – Annotated Example JTIDS Frequency Assignment[31]

005. UE [Unclassified]
010. N [New]
020. T14 [Responsible Frequency Action Officer]
102. AF991234 [Originating Agency Identifier, 99 for CY 1999]
110. M969-1206 [Band, MHz]
111. M1009-1051 [Excluded Frequency Band for ATCRBS radar transmission, MHz]
111/02.M1065-1109 [Excluded Frequency Band for ATCRBS radar reception, MHz]
113. MA [MA-Aeronautical Mobile Aircraft]
114. 9M00Q1D [Bandwidth, pulse waveform types, ..]
115. W200 [200 Watts transmit power]
130. 1 [Time of Use, 1-Regularly, not limited to work week]
141. 20010831 [Expiration data]
144. Y [Process through Interdepartmental Radio Advisory Committee (IRAC)]
200. USAF [Responsible Service]
202. ACC [MAJCOM responsible for the installation]
204. ACC [MAJCOM responsible for the operating unit]
205. 12AF [NAF]
206. MTNHOME [Installation]
207. 366WG [Operating Unit]
208. JTIDS
209. DOD AFC/JFMO [Area Frequency Coordinator]
[300 series treats transmission characteristics]
300. ID [Tx State/Country]
301. MTNHOME [Tx antenna location]
303. 430300N1155300W [Tx coordinates or coordinates of radius of operation center]
306. 450B [Authorized radius for mobile radios in kilometers, B-both transmit and receive]
340. G,AN/URC-107 [JTIDS Class 2 terminal designation]
340/02. G,AN/URQ-33 [JTIDS Class 1 terminal designation]
343. 4413 [Equipment Allocation Number for JTIDS]
362. ND [Nondirectional antenna]
363. V [Vertical polarization]
[400 series treats reception characteristics]
400. ID [Rx State/Country]
401. MTNHOME [Rx antenna location]
440. G,AN/URC-107 [JTIDS Class 2 terminal designation]
440/02. G,AN/URQ-33 [JTIDS Class 1 terminal designation]
443. 4413 [Equipment Allocation Number for JTIDS]
[500 series are IRAC notes. These can include important assignment constraints (see C067). Brackets only paraphrase notes. For actual notes refer to Air Force Manual 33-120]
500. P032 [Operation on non-interference basis]
500/02.E039 [Bandwidth as specified in item 110]
500/03. S362 [One or more transportable Tx/Rx stations are utilized in assignment]
500/04. S085 [Training and testing operations]

[31] This is a fictitious frequency assignment which has been prepared only to illustrate the format

8.8-2 Frequency Management – Annotated Example JTIDS Frequency Assignment[32]

500/05. C067 [Subject to coordination with Area Frequency Coordinator (AFC) located at Nellis AFB before use in Nevada, Utah West of 111° W and Idaho South of 44° N.]
[501 series are Free Text notes]
501. M015, IRAC 27439 [Updated JTIDS waveform approval letter, NTIA dated 30 July 91]
501/02. M015, IRAC 28843 [Interim terminal certification, NTIA letter dated 7 June 94]
501/03. M015, IRAC 21167 [Orig JTIDS waveform approval letter, NTIA dated 6 Dec 79]
[502 series represents a description of the requirement and constraints on assignment use]
502. USE IS CONTINGENT UPON DOD INTERNAL COORDINATION AND PULSE 502. DECONFLICTION IAW CJCSI 6232.01[33]. AUTHORIZATION ABOVE 100/50/20
502. TSDF MUST BE REQUESTED. REQUESTS FOR AREAS NOT LISTED ABOVE 502. OR FOR GREATER THAN 100/50/20 TSDF OPS SHOULD BE SUBMITTED AT 502. LEAST 90 DAYS IN ADVANCE OF THE REQUIREMENT. DIRECT LIAISON
502. WITH FAA IS PROHIBITED. PLATFORMS NOT IDENTIFIED AND
502. AUTHORIZED BY NTIA FOR 100/50/20 TSDF OPS ARE LIMITED TO NO MORE 502. THAN 40/20 TSDF. CONTACT NAVEMSCEN FOR THE OFFICIAL LIST[34].
[503 series represents additional text comments]
503. MAXIMUM 100/50/20 TSDF, ELSE 40/20 TSDF
503/02. CLASS 1, 2, 2M AND 2H TERMINALS
503/03. AUTHORIZED PLATFORMS[35] E-3, RC-135, E-8, CRC/MCE/JM, ABCCC, F-15, 503/04. E-2, F-14
[520 series represents supplemental details and can include added important constraints]
520. COORD FAA-CHRISTEIN NAVEMSCEN-DOWNIE AR-WEAVER.
520. OPS LIMITED TO 100 PERCENT TSDF IN A 200 NM RADIUS OF EACH
520. TERMINAL. NO MORE THAN 50 TSDF PERMITTED FOR ANY JTIDS
520. TERMINAL. CONTENTION TRANSMISSIONS LIMITED TO ONLY THE
520. FOLLOWING: NET ENTRY/PPLI, AND FIGHTER-TO-FIGHTER MSGS[36].
520. MODE-S SEPARATION DISTANCE SET AS –22 DBM AT THE RCVR. ATCRBS 520. SEPARATION DISTANCE SET AS –20 DBM AT THE RCVR.
520. TACAN/DME BEACON TOTAL TSDF LIMIT IS 50 PERCENT WITHIN 7 NM
520. RADIUS AND NO TERMINAL CLOSER THAN .5 NM. 200 WATT MAX

[32] This is a fictitious frequency assignment which has been prepared only to illustrate the format
[33] This represents the requirement for deconfliction of independent network operations in close proximity. It is discussed further subsequently.
[34] The NTIA letter approving the Class 2 terminal for uncoordinated use (i.e., for use any time without reporting each use to the FAA case-by-case) does not so approve it for all platforms. Some platforms are perceived by the FAA to have cosite problems (i.e., the JTIDS transmissions are thought to impact on the performance of the ATCRBS beacon) and so are limited to 40/20 (i.e., total transmissions of those platforms within 200 nm of a JTIDS terminal must not exceed 40% and no one such platform can exceed a 20% TSDF). Since the signing of the letter other developments have taken place and NAVEMSCEN provides updated information on individual platforms.
[35] The long term intent is to have all JTIDS/MIDS platforms authorized, hopefully on a common assignment or, at least, on relatively few assignments.
[36] The contention access transmission mode is thought to have a more significant impact on navigation aids than does dedicated access, so the FAA has constrained its use to Round-Trip-Timing (RTT) and net entry messages for synch, and PPLIs and other fighter-to-fighter exchanges (i.e., beyond synch its use is intended for fighter transmissions)

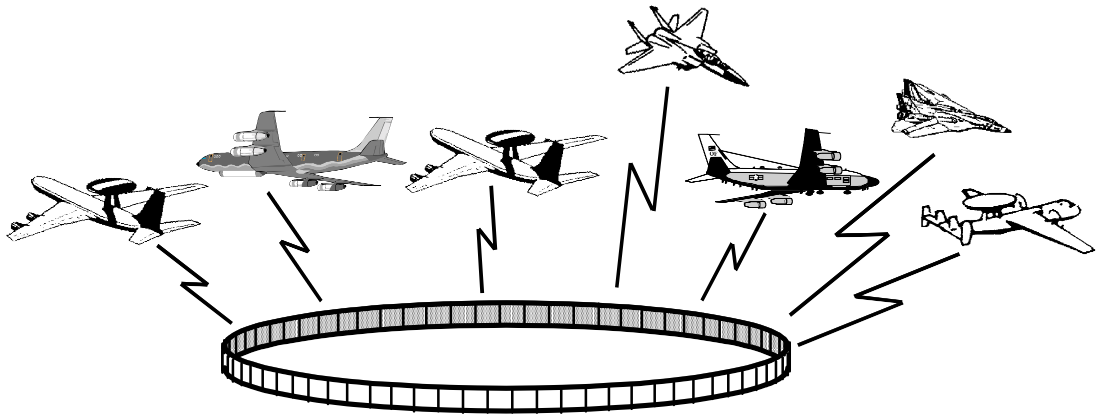
8.8-3 Frequency Management – Annotated Example JTIDS Frequency Assignment[37]

520. OUTPUT. EMC FEATURES OPERATIONAL.
520. ALL A/C WITHOUT ATTENUATION TO LIMIT JTIDS SIGNAL BELOW
520. 1030/1090 MHZ ATCRBS RX MTL [38]ARE RESTRICTED TO DATA SILENT OPS
520. OUTSIDE MOAS UNLESS OPERATING UNDER POSITIVE PRIMARY RADAR
520. CONTROL. FOR ALL JTIDS OPS OUTSIDE MOAS WHICH EXCEED 40/20 TSDF
520. OR INCLUDE VOICE, NOTIFY FAA ASR 100 ONE WEEK PRIOR TO OPS VIA
520. MAJCOM[39]. STOP BUZZER POC 390 FIGHTER SQUADRON CMD POST (208)
520. 848-2092
701. T14
702. CONTROL/REQUEST NUMBER
705. SPECIAL PROJECTS, JTIDS

[37] This is a fictitious frequency assignment which has been prepared only to illustrate the format

[38] All aircraft without attenuation to limit the JTIDS signal to below the 1030/1090 MHz minimum triggering level (MTL) means fighters in this example assignment.

[39] If the total TSDF of fighters operating outside of MOAs must exceed 40% and/or fighters outside of MOAs must use voice, the FAA must be informed on a case-by-case basis.



8.9 Frequency Management – Total TSDF for a Small Isolated Network

Assume for the moment that we are going to operate a Link 16 network, all of our platforms lie within 200 nm of one of the network participants and that there are no platforms operating in another independently operated Link 16 network within 200 nm of any of our network participants. Assume further that the TSDF constraints for the frequency assignment under which we are operating is 100/50/20, the norm. The DOD must ensure that the sum total of the individual platform TSDFs does not exceed 100%.

When a network is designed, the associated network description will include a pulse density calculation table. The table will list the individual TSDF of each platform in the network and for each JTIDS/MIDS voice group in the network. When totaling the individual platforms in the network as designed, it may be that the total TSDF is well in excess of 100%. This is perfectly all right. What matters is the total TSDF of the network as used, not the network as designed. For example, the Air Force and Navy might coordinate on a network which includes a Class 1 equipped E-3, a Class 2 equipped E-3, a JSTARS, a Rivet Joint, up to 12 F-15s, an E-2 and up to 8 F-14s with two 2.4 kbps voice groups for the Air Force and one 16 kbps voice group for the Navy. If all of these platforms were to use the network at the same time, the total TSDF would exceed the 100% constraint. However, the network is not intended to be used with all platforms at the same time. It was designed to permit the F-15s, normally a four-ship flight, to train with an E-3 and Rivet Joint, and for the E-3 to be either Class 1 terminal equipped or Class 2 terminal equipped. It will also permit the F-15s and Rivet Joint to work with an E-2 and F-14s should such a joint training exercise be desired. It will also permit a JSTARS to move in with an E-3, the F-15s and Rivet Joint to train. These are all supported by the one network and doing it with one network simplifies the management of the JTIDS network library. What is important is not the total TSDF of the network, but the total TSDF of the segment of the network being operated at any given time. <u>It is the responsibility of the wing manager to ensure that the total TSDF of any network in which his platforms are participating is less than the total TSDF constraint imposed by the frequency assignment under which they are operating.</u>

Pulse Density Calculations: **AFBU000xA**

PLATFORM	TSDF DATA (w/o relay)	TSDF DATA (w relay)
E3I(1)	4.3%	
E3(1)		29.2%
RJ(1)	2.2%	
JSTARS	3.7%	
CRC(1)	7.3%	
E2(1)	7.3%	29.2%
F14(1)/8	2.7% per ftr	
F15(1)/12	3.3% per ftr	
Voice A (Air Force)	8.3%	
Voice B (Air Force)	4.2%	
Voice A (Navy)	12.5%	

8.10-1 Frequency Management – TSDF Calculations

Suppose that we are going to operate the AFBU000xA network with a Class 2 E-3, Rivet Joint, CRC and two four-ship flights of F-15s. The geography is such that Rivet Joint and the CRC are within 200 nm of the E-3. The fighters certainly may be within 200 nm of the E-3. We will operate Voice A on net 0 as a interC^2 unit channel, and Voice B on net 1 for the E-3 and the fighters it is controlling and on net 2 for the CRC and the fighters it is controlling. In the network design the E-2 has the option of relaying (i.e., if the E-3 is not present) since, for them, this can be selected in the aircraft. If it is to be designated as relay, its TSDF with relay will be used in the calculation of total TSDF. However, in this example, the Navy is not present.

For the per unit TSDF calculations we must add voice to data. The voice capabilities of the platforms are as follows:

E3I – Voice A only.
E3 – Voice A and B, simultaneously if assigned
RJ (by late CY99) – Voice A or B, only one at a time
JSTARS – No voice capability
CRC – Voice A and B, simultaneously if assigned
F15 - Voice A or B, only one at a time
E2 - Voice A and B, simultaneously if assigned
F14 - Voice A and B, simultaneously if assigned

In this application, to check the per unit TSDFs we must add voice to the data. For the E-3 and CRC this results in 41.7% and 19.8%, respectively. Therefore, the E-3 must be operating above 18000 ft MSL, and will be by procedure[40]. The CRC is less than 20% as required. For the Rivet Joint and the F-15s, only the worst case voice group need be added to the data since these platforms cannot physically use both voice groups at the same time.

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[40] The E-3 does not begin to use its terminal until it has sufficient cooling air which is so far into the mission that it is normally above 18000 ft MSL. If not, the communication technician has little time to wait until the aircraft passes through 18000 ft MSL as it climbs to its cruising altitude of about 29000 ft. At the completion of its mission, as it leaves its orbit at cruising altitude, the E-3 normally powers down its JTIDS terminal.

Pulse Density Calculations: **AFBU000xA**

PLATFORM	TSDF DATA (w/o relay)	TSDF DATA (w relay)
E3I(1)	4.3%	
E3(1)		29.2%
RJ(1)	2.2%	
JSTARS	3.7%	
CRC(1)	7.3%	
E2(1)	7.3%	29.2%
F14(1)/8	2.7% per ftr	
F15(1)/12	3.3% per ftr	
Voice A (Air Force)	8.3%	
Voice B (Air Force)	4.2%	
Voice A (Navy)	12.5%	

8.10-2 Frequency Management – TSDF Calculations

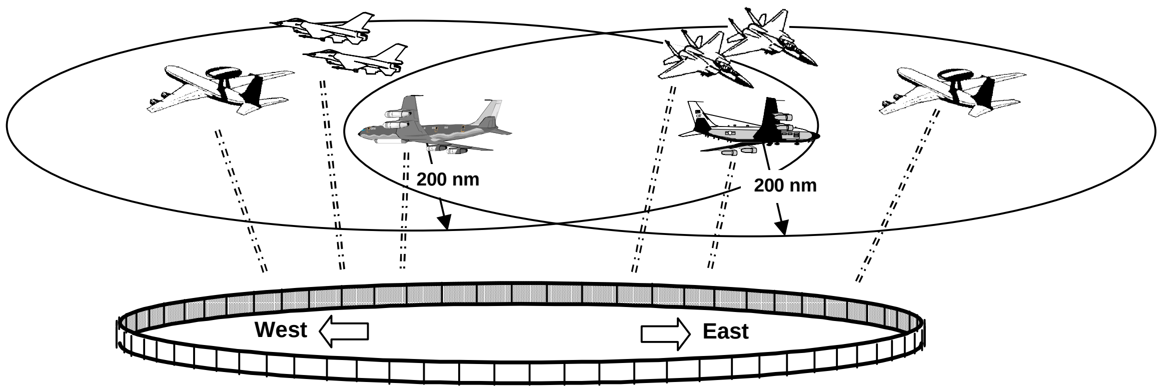
The resulting TSDFs for the Rivet Joint and the F-15 are 10.5% and 11.6%, respectively. The F-15s must be operating with their local assignment within their MOAs[41].

For the total TSDF we first count the data for each participant which results in 29.2%+2.2%+7.3%+8x3.3%=65.1%. To this we must add voice.

The use of voice and just how to count it in calculating TSDFs is an issue between the DOD and FAA which is being worked. The AF JNDF will keep the Air Force Link 16 community informed of progress in this area via their web site. To date, the Air Force approach has been to count each voice group/net combination being used. The JTIDS voice channels are used very lightly right now, and the operators use "push-to-talk" protocols to prevent more than one user transmitting on a given group/net at the same time. However, while the use is light, it is conceivable (although unlikely) that up to one user per group/net might be using JTIDS voice. After all, they can't hear one another. Therefore, to be conservative until the issue is resolved, the Air Force counts each group/net in use. In this example that is one net of voice group A, and two nets of voice group B, for a total voice use of 16.7%. The total for the network is the sum of the data and voice with a resulting total TSDF of 65.1%+16.7%=81.8%, well within the 100% constraint.

Remember, it is the responsibility of the wing manager to ensure that the total TSDF of any network in which his/her[42] platforms are participating is less than the total TSDF constraint imposed by the frequency assignment under which they are operating. This will[43] require the ability to calculate the total TSDF of the network in which they are operating.

[41] Otherwise they can't use voice at all.
[42] All roles discussed in this document can be done by both men and women. However, rather than use unwieldy split pronouns throughout the text, we will use only the male gender. It should be recognized that we actually mean either men or women.
[43] If the wing manager's platforms are operating in a network being managed by another unit or agency (e.g., ASCIET), the wing manager may count on that agency to have calculated the total TSDF correctly, but he will have to calculate TSDFs for his own operations.



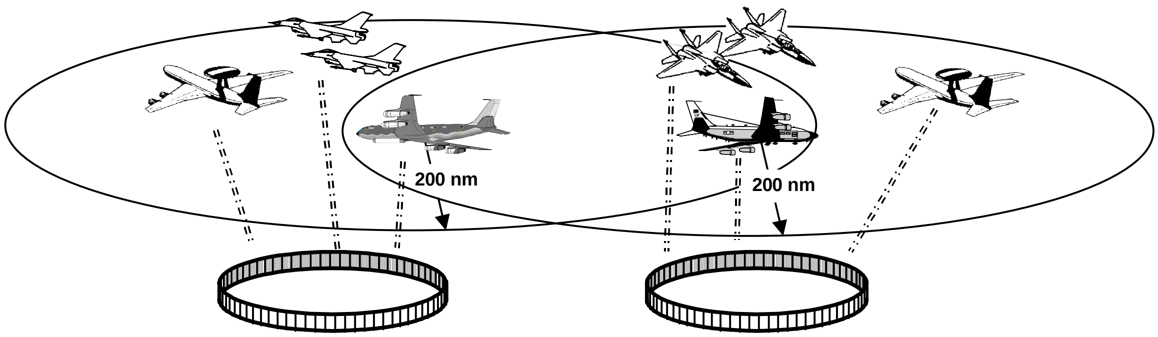
8.11 Frequency Management – Large Scale Networks

As previously discussed, the 100% TSDF constraint applies to each Link 16 participant and requires that the total TSDF of all Link 16 participants operating within 200 nm of the participant be no more than 100%, independent of the networks in which they are operating. It is only a network constraint for a given network if there are no other Link 16 participants operating within 200 nm of any of the network participants and, the network participants all lie within 200 nm of one of the network participants.

In the figure we depict a single network which is geographically distributed. In the east we are conducting counterair operations with an E-3, Rivet Joint and F-15Cs, and in the west we are conducting interdiction with an E-3, JSTARS and F-16s. The east E-3, F-15Cs and JSTARS are within 200 nm of the Rivet Joint, and so must total no more than 100%. Since the F-16s movement area may change, it would be wise to count them in this total as well. The west E-3 need not be included as long as it will maintain a strict orbit in the west. Similarly, the west E-3, JSTARS, Rivet Joint and the fighters must total no more than 100%, as long as the east E-3 maintains a strict orbit in the east. Note that the network TSDF can exceed a 100% TSDF while still satisfying the 100% constraint[44]. Of course, to utilize more than 100% this geographic situation must be maintained (i.e., the west E-3 cannot move east to support the counterair operation and visa versa). Keeping the entire network within 100% would provide complete flexibility of locations, but might unduly restrict capacity. This decision must be made by the network manager before the network is designed since packing limit is part of each C^2 platform's initialization load[45]. However, it can be altered by the network manager before the network is put into operation or even while it is in operation since the E-3 communication technician can change the packing limit via the Control Monitor Set (CMS) in the aircraft[46]. Communication operators in the Rivet Joint, JSTARS and the CRC can also change the packing limit from the aircraft/module, respectively.

Since this network has all been assumed to be operating in isolation, it is relatively easy for the network manager to ensure the 100% constraint is met. He alone is in charge.

[44] This can occur in a network design which uses packed four, perhaps for the surveillance function.
[45] Fighters do not transmit surveillance and packing limit need not be specified for reception. The terminal automatically receives whatever packing limit is being transmitted.
[46] This is not current practice and some training is required if this approach is to be adopted.

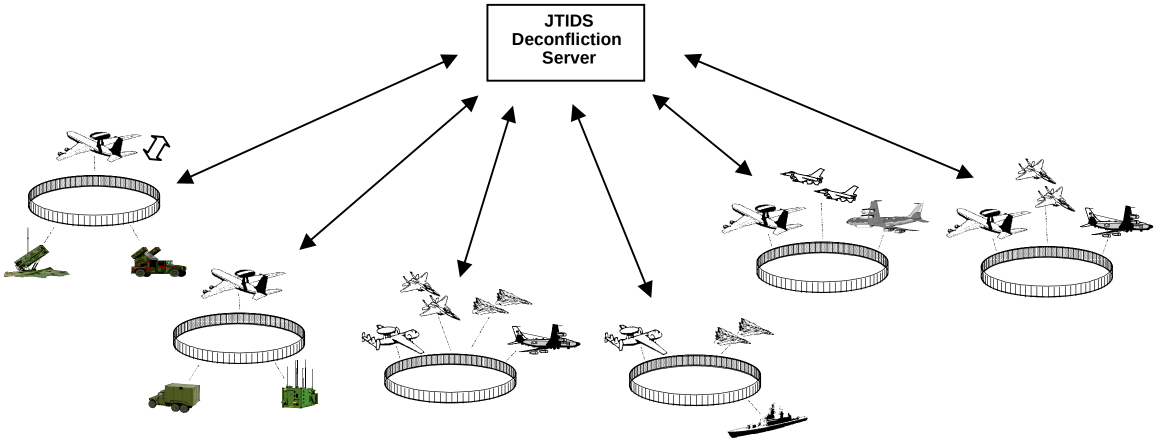


8.12 Frequency Management – Frequency Deconfliction

This figure shows the same geographic situation as the previous subsection except that the two operations are being conducted as two independent[47] networks. The same constraint regarding total TSDF applies to this situation. It is independent of the number of networks in operation. As with the one network case, it is simplest and provides the most flexibility of movement if the sum of all participants of both networks are counted against the 100% total TSDF constraint, but this may impose too much of a capacity restriction. If it does, the 200 nm radius can be applied on an individual participant basis as described for large scale networks.

The constraints for a single isolated network can be ensured by the network manager. But how do we ensure that the constraint is maintained with two (or more) independent networks in operation in close proximity? Again, if the same network manager is managing both networks, its simple since he is responsible for both operations. An example of this would be if the 366 WG at Mt Home AFB is operating two independent training networks in two of their MOAs[48]. Both operations would be coordinated with the wing manager. However, with the deployment of Link 16 widening, we will increasingly find training networks being operated by different bases and agencies in relatively close proximity. The operation of these networks must to be coordinated to ensure that the 100% total TSDF constraint is met. This coordination is termed frequency deconfliction. <u>In the Air Force it is the responsibility of the wing manager to ensure frequency deconfliction is performed for all Link 16 operations in which his platforms take part</u>. The process of deconfliction is described in CJCSI 6232.01A entitled Deconflicting JTIDS/MIDS Operations. This subsection draws on material from that instruction and the Spectrum Users Guide.

[47] For example, using different cryptokeys
[48] or a Blue flight vs Red flight operation in the same MOA.

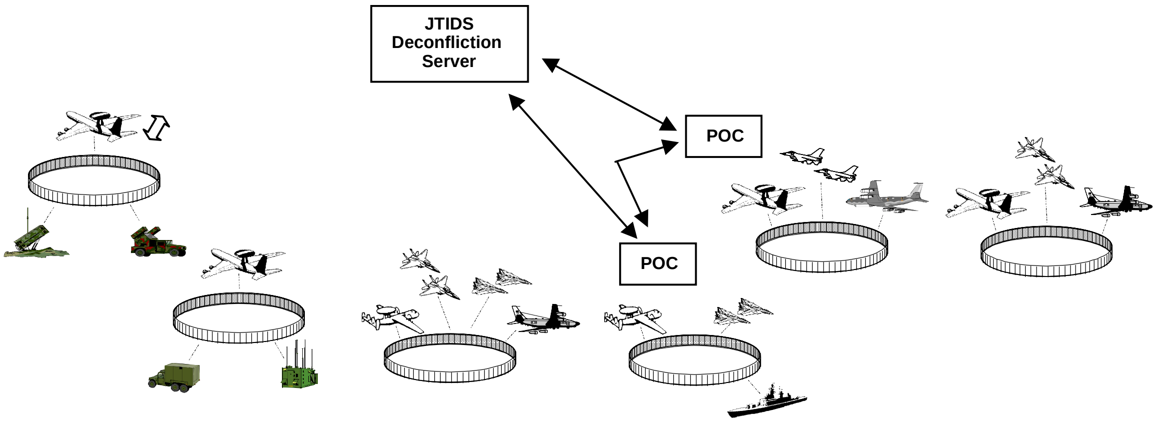


8.13 Frequency Management – Frequency Deconfliction Server

In order to coordinate all operations in close proximity to his operations the wing manager has to know about them. This is accomplished thorough the use of the JTIDS deconfliction server. The deconfliction server is a database of Link 16 operations within the US&P maintained on a web site located at FORSCOM[49]. The wing manager will require a password to access the deconfliction server and the web site supports application for one. In this database the wing manager will find all of the scheduled Link 16 operations within the US&P. How this database is generated and just what an "operation" is will be discussed subsequently. For this discussion, assume that an operation is a network. For each operation the data base will contain a primary point of contact (POC), the name of the operation if appropriate (e.g., ASCIET 99), the associated OPTASK LINK reference if appropriate, the name of the network, the short title of the main cryptokey, the area(s) of operation, the time of operation (i.e., start time and end time) and the TSDF in use, both the total and the maximum per unit TSDF. With this information the wing manager can deconflict his own operation as it is planned.

The wing manager will know where and when his planned operation is to take place and can calculate both the per unit and total TSDF he wishes to use. Then he searches the deconfliction server data base for any operation already scheduled with its area of operation lying within 200 nm of any of his participants. If he finds none then his operation can be scheduled on the deconfliction server as is. Just how this is done will be discussed subsequently. If he finds one (or more) operations which does have an area of operation within 200 nm of one of his participants, then his operation combined with the other operation must satisfy the 100% total TSDF constraint. As a first step, the manager should look to see if the sum of the total TSDFs from his operation and the other operation exceeds 100%. If not, he can go ahead and schedule his operation. If the sum does exceed 100%, he can look to see if the subtotal TSDF of all of his participants who will be within 200 nm of the other operation's area of operation added to the total TSDF of the other operation will exceed 100%. If not, he can go ahead and schedule his operation. If so, he will have to contact the POC of the other operation for more information and, perhaps, some "horse trading".

[49] http://jndl.forscom.army.mil, the JTIDS Network Design Library (JNDL) at Ft McPherson, GA.



8.14 Frequency Management – The Deconfliction Process

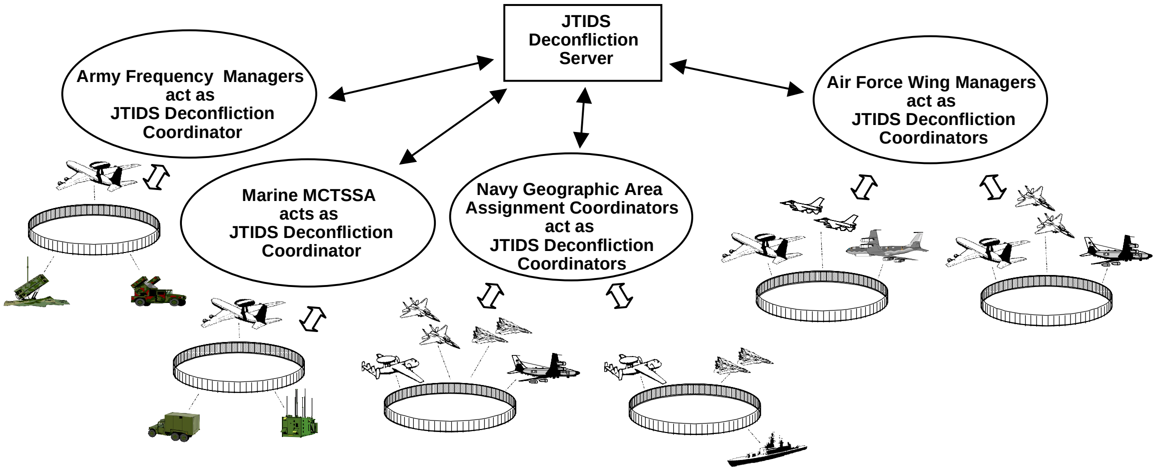
The DOD wishes to have frequency utilization conflicts resolved at the lowest possible level. When a wing manager finds that his planned operation is in conflict with an operation already scheduled he should contact the POC for the other operation directly. It is possible that additional participant location information will permit the two operations to go forward as planned. It is possible that the scheduled operation has been overly conservative in total TSDF or time of use, and that the other POC can reduce his total TSDF for the time required. It is possible that the other POC will relocate participants to support combined use.

In some cases, conflicting operations will be the norm. The operations at Mt Home AFB and NAS Fallon NAS may be such an example when Link 16 operations become the norm at NAS Fallon[50]. In such cases it will be well for the units to consider developing standing agreements regarding use of the spectrum. For example, the Fallon POC and the Mt Home wing manager might each agree to utilize no more than a 50% total TSDF in the areas for which participants from the two operations might be within 200 nm of each other. This would keep the combined total in such areas within the 100% total TSDF constraint. Only when exceptions are required would direct contact and negotiation be required.

If local POCs cannot resolve the conflict, the first common commander will perform the function. It should not be inferred that the first unit to schedule will get priority. A unit preparing for an unscheduled and imminent operational deployment would certainly be given priority over normal daily training. When no common commander exists, the Joint Staff JTIDS/MIDS Deconfliction Authority will resolve the issue. If no lower level joint authority can be found, the ultimate authority is Joint Staff, J-6.

However, resolution of frequency utilization conflicts at the lowest possible level is encouraged.

[50] When the F/A-18 is equipped with the MIDS/LVT.



8.15 Frequency Management – Deconfliction Coordinators

The POCs in the deconfliction process are termed deconfliction coordinators. Only service offices that have been designated as a deconfliction coordinator can enter planned Link 16 usage into the deconfliction server database. The telephone numbers of the deconfliction coordinators are included for each scheduled operation in deconfliction server database. The Air Force has designated their Link 16 wing managers as deconfliction coordinators. Link 16 operations scheduling is illustrated in the figure.

For the Navy, Link 16 operations have been divided into several geographic areas. The Navy deconfliction coordinators are termed Geographic Area Assignment Coordinators (GAACs) and are associated with each Link 16 operations area. There are three areas along the East Coast covered by the Fleet Area Control Scheduling Facilities (FASCFACs) at Oceana, VA; Jacksonville, FL; and Roosevelt Roads, PR. There are seven areas in the west covered by CINCPACFLT Pearl Harbor, HI: FACSFAC San Diego, CA; FACSFAC Pearl Harbor, HI; NAVSHIPYD Puget Sound, WA; NAVCOMTELSTA Guam, NAVSTKAIRWARCEN Fallon, NV; and MCAS Yuma, AZ. When dealing with Navy operations the POC with which the wing manager will deal will be one of these GAACs[51].

The Army deconfliction coordinators are located at White Sands Missile Range, NM and the Army National Training Center at Ft Irwin, CA. The Marine deconfliction coordinator is located a Marine Corps Tactical System Support Activity (MCTSSA) at Camp Pendleton, CA.

[51] Although it is expected that the GAAC may put the wing manager in direct contact with the operational unit to discuss the details of the operation.

Pulse Density Calculations: **AFBU000xA**

PLATFORM	Contribution to Total TSDF	Per Unit TSDF with Voice
E3(1)	29.2%	41.7%
RJ(1)	2.2%	10.5%
CRC(1)	7.3%	19.8%
F15(1)/8	3.3%x8=26.4%	11.6%
Voice A/Net 0 intraC^2	8.3%	
Voice B/Net 1 E-3 Control	4.2%	
Voice B/Net 2 CRC Control	4.2%	
Total	81.8%	

8.16 Frequency Management – Scheduling Operations

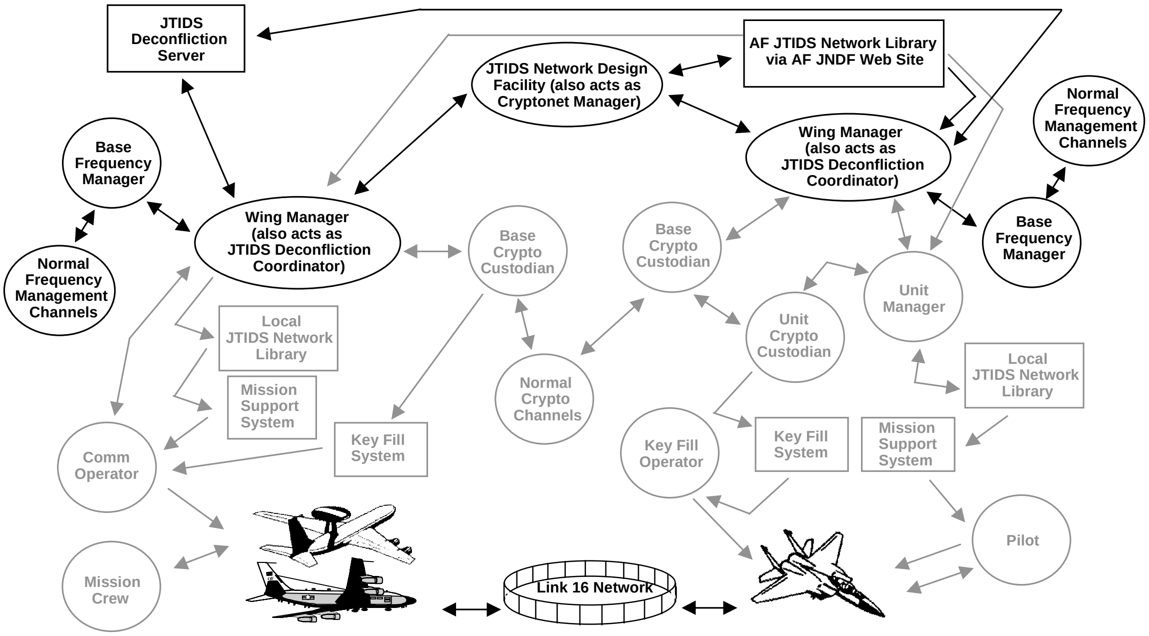
We refer to the network used to illustrate TSDF calculations. The operation is one in which an E-3 from Tinker AFB and a Rivet Joint from Offutt AFB fly to Mt Home AFB for a training exercise. At Mt Home they will set up in orbits outside the F-15 MOAs. Up to two four-ship flights of F-15Cs will work with the CRC of the 726ACS and the two airborne C^2 units. The individual contributions to the total TSDF are shown in the figure with the total TSDF being 81.8%. The maximum per unit TSDF is exhibited by the E-3 at 41.7%.

<u>It is recommended that the wing manager of the base hosting a training operation schedule the operation on the deconfliction server</u>. With this approach the operation being scheduled represents an entire network (or networks[52]). In this example the Mt Home wing manager would schedule the operation, 81.8% for the total TSDF and 41.7% for the maximum per unit TSDF. It is also <u>recommended that the wing manager of the base hosting a training operation take the lead in the deconfliction of the operation</u>. In this regard, entry of the planned TSDFs into the deconfliction server will prompt an alert to the wing manager if there are or may be other operations which impact on the planned operation. This procedure is available to the wing manager in his conduct of the deconfliction process.

There is a precedence for having each wing manager of platforms involved in an operation schedule his platforms on the deconfliction server. However, there are problems associated with this approach. In the example situation, the 522 ACW wing manager might enter 41.7% for the E-3's total and maximum per unit usage. The 55 WG wing manager might enter 10.5% for the Rivet Joint's total and maximum per unit usage. The Mt Home wing manager would enter for both the F-15s and CRC, perhaps with a total TSDF of 7.3%+26.4%+12.5%=46.2% and a maximum per unit TSDF of 19.8%. Notice that the sum of the total TSDFs thus reported by the three wing managers is 98.4%, well in excess of the true total of 81.8%. If this exceeded 100% it would falsely indicate conflict. Even if below the 100% constraint, it improperly deprives other units of capacity[53]. This is certainly not the intent of the deconfliction process. Therefore, <u>if the operation of a single Link 16 network is to be reported upon via the individual wing managers of the platforms comprising the network, the wing managers must coordinate on their reported TSDFs so as to report an accurate total TSDF for the network operation</u>.

[52] For example, if the operation involves independent Blue force and Red force networks.

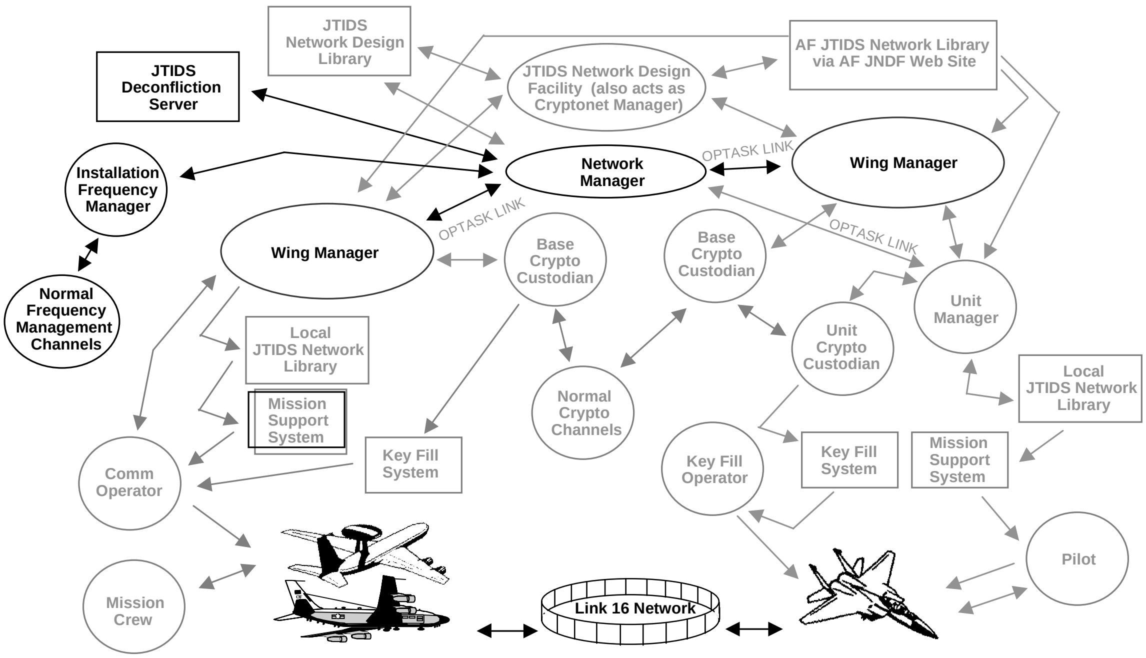
[53] For example, with a 81.8% total, a third four-ship flight could operate an independent network within the 100% constraint, but not with a 98.4% total.



8.17 Frequency Management – In Garrison Frequency Management

The figure depicts the wing manager interfaces for frequency management during daily training. Within the Air Force, the wing manager is responsible for ensuring that (i.) constraints regarding the distance of his platforms from radionavigation aids and ATCRBS radars are met, (ii.) his platforms are operating appropriately under a valid a frequency assignment, and (iii.) the operations of his platforms have been deconflicted from the operation of other platforms in the same vicinity. The wing manager should seek advice from the AF JNDF regarding the availability of frequency assignments which would be applicable to wing use, the requirement for a local frequency assignment, what is reasonable to request for a frequency assignment given past experience and the format for the request. The request will be made via the base installation frequency manager (IFM) through normal frequency management channels, but the wing manager should work with the AF JNDF and his IFM to set the operational requirements for his assignment(s).

The wing manager has been designated the deconfliction coordinator for his platforms. It is the responsibility of the wing manager to ensure that frequency deconfliction is performed for all Link 16 operations in which his platforms take part and that the use of Link 16 by his platforms is scheduled in the deconfliction server data base. It is recommended that the wing manager of the base hosting a training operation schedule the entire operation on the deconfliction server including the platforms from other bases. Independent scheduling by the wing managers of individual platforms comprising the operation can lead to improper scheduling. Therefore, if the operation of a single Link 16 network is to be reported upon via the individual wing managers of the platforms comprising the network, the wing managers must coordinate on their reported TSDFs so as to report an accurate total TSDF for the network operation.



8.18 Frequency Management – Deployed Frequency Management

The figure depicts the wing manager interfaces for frequency management during deployed operations. By deployed operations we mean to a daily training exercise hosted by another base, to an exercise operated by a separate authority (e.g., ASCIET, Red Flag), to a Military Operation Other Than War (MOOTW) such as Southern Watch and to a theater of war (e.g., the Gulf during Desert Storm). In these instances the host of the operation has the primary responsibility for frequency management regarding his operation (e.g., the Joint Interface Control Officer (JICO) of a MOOTW operation). However, <u>the wing manager should query the operations manager to satisfy himself that the frequency management responsibilities are being properly carried out, particularly with respect to his participating platforms</u>.

In garrison responsibilities in support of operations managed by personnel other than at wing:

6. To provide guidance to their operators regarding frequency management, the DOD has published two important documents, the JTIDS/MIDS Spectrum Users Guide and Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 6232.01A. Wing managers should be familiar with these documents. They are posted on the AF JNDF web site. Reference: para 8.1-2

7. Ensure that wing platforms operating in Link 16 networks are doing so under valid frequency assignments.Reference: para8.2

   a. For deployed operations review the assignment under which wing platforms will operate

   b. Be familiar with Air Force Manual 33-120 entitled Radio Frequency (RF) Spectrum Management which will permit the wing manager to understand the frequency assignments

8. Ensure that wing platforms are operating in accordance with the constraints expressed in the frequency assignment under which they are operating. Constraints regarding: Reference: para 8.17

   a. The distance of his platforms from radio navigation aids and ATCRBS radars

   b. The total TSDF of any operation in which his platforms participate (i.e., deconfliction)

   Note that the combat IPF setting is not authorized for use during normal peacetime operations

9. Ensure that frequency deconfliction is performed for all Link 16 operations in which your platforms take part and that the use of Link 16 by your platforms is scheduled in the deconfliction server data base.Reference: para 8.12

   a. The wing manager should query the deployed operations manager to satisfy himself that the frequency management responsibilities are being properly carried out including the posting of the operation on the deconfliction server, particularly with respect to his participating platforms.

Operating JTIDS/Link 16 with the procedures and within the constraints set down by the NTIA and the FAA is critical, and failure to do so can have serious consequences. The DOD operates JTIDS/Link 16 in the radionavigation aids band as a secondary user and will continue to be permitted to share the band only if they operate the data link system properly.

Network manager responsibilities for daily training network operations:

16. Ensure that wing platforms operating in Link 16 networks are doing so under valid frequency assignments. Reference: para 8.17

   a. For local training operations ensure that there is an appropriate frequency assignment

      - Consult with AF JNDF to determine availability of existing assignments suitable for wing use.

      - If no existing assignment is suitable, work with the local installation frequency manager (IFM) to request and obtain suitable frequency assignment(s). The AF JNDF can help.

   b. Be familiar with Air Force Manual 33-120 entitled Radio Frequency (RF) Spectrum Management which will permit the wing manager to understand the frequency assignments

8.19-1 Frequency Management – Wing/Unit Manager Checklist

This checklist is an extension of that started in the Network Management I section. It will be extended in subsequent sections and summarized in Network Management II.

Network manager responsibilities for daily training network operations (continued):

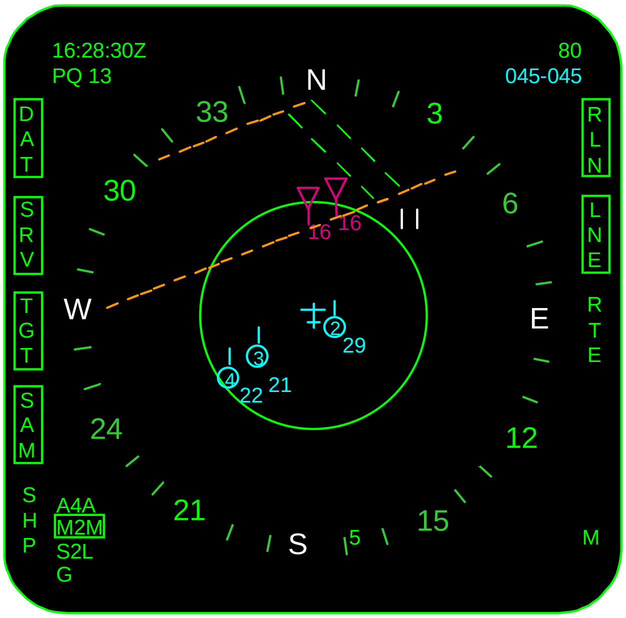
17. Ensure that frequency deconfliction is performed for all Link 16 operations in which his platforms take part and that the use of Link 16 by his platforms is scheduled in the deconfliction server data base. Reference; para 8.13

    a. It is recommended that the wing manager of the base hosting a training operation take the lead in the deconfliction of the operation, and that the wing manager of the base hosting a training operation schedule the entire operation on the deconfliction server.

    b. However, if the operation of a single Link 16 network is to be reported upon via the individual wing managers of the platforms comprising the network, the wing managers must coordinate on their reported TSDFs so as to report an accurate total TSDF for the network operation.

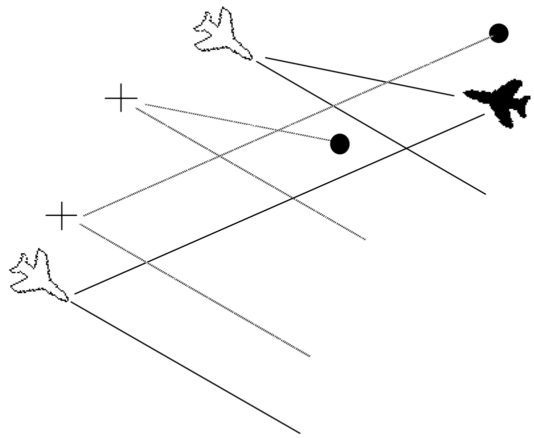
8.19-2 Frequency Management – Wing/Unit Manager Checklist

9.0 Navigation



9.1-1 Navigation – Motivation

An example of the F-15C multipurpose color display (MPCD) is shown in the figure. Four flight members are shown in the center of the display with ownship located directly in the center and indicated with an aircraft symbol. The wingmen are indicated as circles with their flight position inside. The exchange of PPLIs among fighters thus displayed can provide a picture of where each flight member is with a simple glance. It can effectively “turn night into day”, but only if during daytime a pilot seeing his number two displayed to his right does not look out the window and see his number two flying on his left! Since the location reported in the PPLI is based on ownship navigation, the exchange of reliable PPLIs requires accurate fighter navigation.



9.1-2 Navigation – Motivation

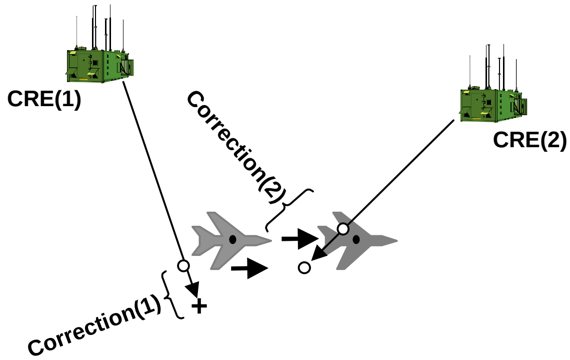
In addition to the direct use of ownship navigation for PPLIs, ownship navigation is used in the exchange of radar targets. In the above figure, each aircraft locates a target quite accurately with respect to ownship location (as depicted with the hollow aircraft symbols). However, both fighters have navigation errors, the + below the top aircraft being where it thinks it is, and the + above the bottom aircraft being where it thinks it is. Before the target is reported out on the data link its absolute location is calculated by adding the radar derived location relative to ownship location. Thus the ownship location error is inserted into the target report. The effect is seen in the figure. The top aircraft reports a target low and to the left of the target being reported by the bottom aircraft. At issue for both aircraft is whether there are, in fact, two targets or one.

To establish whether there are two targets or one, each fighter will use target correlation algorithms based, in part, on how far apart the reported target positions are. If the navigation error can be big, the "correlation window[1]" can be made big too so a single entity will be interpreted correctly. However, a big correlation window may lead two close spaced entities, one seen by one aircraft and the other seen by another, to be falsely correlated to one entity. Such false correlations can lead to nasty surprises as the friendly fighters close on the hostiles. So, inaccurate navigation leads to poor radar target correlation.

Unfortunately the F-15C inertial navigation system (INS) has a significant drift rate when considering Link 16 applications, about 0.7 nm/hr. Given INS alignment early in preflight operations on the ramp, significant drift can occur even before the fighters take off. Fortunately, JTIDS/Link 16 terminals provide a relative navigation capability. This capability is critical to the employment of Link 16 by the F-15Cs.

The need for ownship navigation accuracy is also important for surveillance platforms which also sense tracks relative to ownship and add ownship location before reporting the tracks on Link 16. However, these platforms have been given GPS[2], the F-15Cs have not[3].

[1] A correlation window is a box around each reported target such that another target reported by a different source found within the box is considered the same entity.
[2] Global Positioning System
[3] Whereas the F-15Es and F-16s have been given GPS.



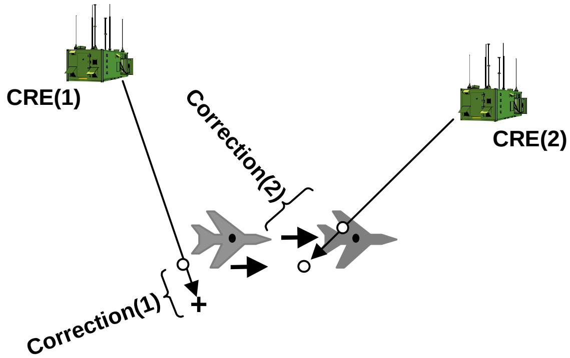
9.2-1 Navigation – Geodetic Navigation

There are two JTIDS navigation modes. Both will be described in this section. However, we will take some liberties in the descriptions to keep the presentation simple, if not entirely accurate, while providing an understanding of how JTIDS navigation works which is suitable for operating with it and conducting troubleshooting. The first of the two modes to be discussed is termed geodetic navigation.

The use of JTIDS geodetic navigation in the F-15[4] is depicted in the figure in which a fighter is flying along (two locations on its path are shown with aircraft symbols) receiving PPLIs from two ground sources. The navigation mode uses position and velocity inputs from the INS provided to the terminal once every 50 msecs. Within the terminal is a mathematical model of the aircraft dynamics. After INS alignment, the terminal takes the first position as provided by the INS as an initial position and begins to use the velocity to move along its position estimate from that position[5] via the model to provide a continuous estimate of aircraft position. Subsequently, the terminal subtracts the position provided by the INS from its own estimate of position and provides the difference as navigation corrections to the F-15 flight processor, once every 50 msec. It also reports the estimated position and velocity (e.g., course and speed) from the model in its PPLI. Based upon the specified drift rate of the INS it also provides an estimate of the errors in the reported position. This is done with a position quality (Pq) in a manner similar to the time quality (Tq). This will be discussed further subsequently.

When the fighter enters the network and begins to receive PPLIs from other participants, they too will be reporting their position and Pq. Two such sites are depicted as CREs in the figure. The terminal will receive each PPLI and measure its time of arrival (TOA) in network time[6]. The navigating terminal knows when the PPLI was transmitted in network time[7] and, with the TOA, can calculate the propagation time from the source. This provides a TOA based range estimate to the source. The navigating terminal will compute the range to the source by subtracting the source reported position from its own estimated position (the estimated position prior to any correction is shown as a + in the figure), compare it with the TOA based range estimate, and compute a range error. It will adjust its

[4] Both the F-15C and the F-15E use geodetic navigation, but the F-15E uses it only as a backup to GPS.
[5] The terminal must be in the normal transmit mode (NORM) when the INS is set to NAV.
[6] However, this will depend upon range mode, and this will be discussed further at the end of this subsection
[7] Any terminal transmitting in the time slot would transmit at the same network time (ignoring individual terminals' synchronization errors).



9.2-2 Navigation – Geodetic Navigation

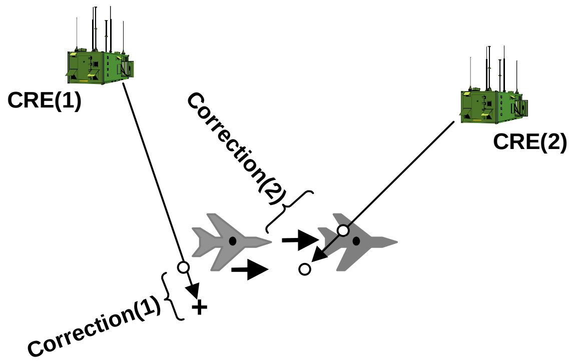
position estimate so as to reduce that error (i.e., in the estimated direction of the source) as long as the Pq of the source is better than its own. It will do this successively for each PPLI it receives, improving and then maintaining its position estimate. In between the reception of PPLIs and the processing of their TOAs, the model will continue to use the INS velocity to move along its position estimate[8]. Two successive updates from the two sources are shown in the figure. The dot inside the aircraft symbol represents the actual position of the fighter. Correction 1, from the + to the o, is based on receipt of a PPLI from CRE(1). After correction 1, the mathematical model with INS velocity inputs moves the estimate along until the PPLI from CRE(2) is received. At that point a second correction is made. The figure depicts a very good estimate is possible for this geometry if the whole range error is corrected for on each of the two successive updates.

However, there will be range estimation errors. These will depend how well the source knows its location (i.e., its Pq) and how well the terminal can estimate the range. The quality of the range estimate will depend on upon how well the terminal can measure the TOA and how well the source and navigating terminals know network time (i.e., their Tqs). Based on the associated position and time qualities, the navigating terminal will judge just how big a correction it should make based on each received PPLI. If the source Pq and the two Tqs are very good, and the uncorrected Pq of the navigating terminal is poor, the correction will be a large portion of the estimated range error. At the other extreme, if there are no good sources relative to the fighter's INS error, the correction will be zero. So <u>good sources of high position quality (Pq) and good time quality (Tq) for the sources and the navigating terminal are required for effective geodetic navigation</u>.

A table defining Pqs is presented below where σ is the standard deviation of the error.

Pq	σ, ft.	Pq	σ, ft.	Pq	σ, ft.	Pq	σ, ft.
15	≤ 50	11	≤ 200	7	≤ 800	3	≤ 4520
14	≤ 71	10	≤ 282	6	≤ 1130	2	≤ 9040
13	≤ 100	9	≤ 400	5	≤ 1600	1	≤ 18080
12	≤ 141	8	≤ 565	4	≤ 2260	0	> 18080

[8] Actually, as successive TOAs are processed, an estimate of the velocity errors and azimuth misalignment errors of the INS can be made. So the position estimate can be moved along with better accuracy than would be realized by use of just the raw inertial velocity.



9.2-3 Navigation – Geodetic Navigation

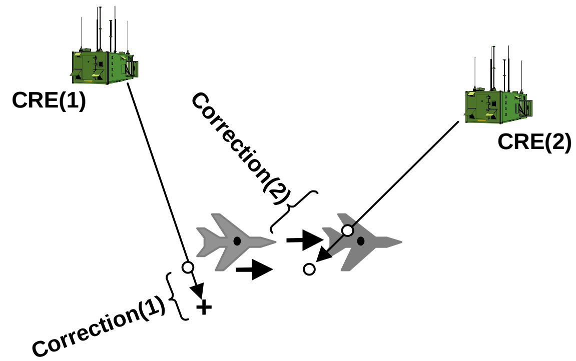
A navigating terminal continuously estimates its position error[9]. From these estimates, it computes an internal position quality, and then reports a position quality which is one less than its internal position quality. Reported ownship position quality is displayed to the pilot in the upper left of the MPCD and is included in the PPLI which the terminal transmits to other terminals.

In order to make a range estimate from the measured TOA, the navigating terminal has to know when, in network time, the received PPLI was transmitted. As described in modes of operation, the terminal can be operated in two range modes, normal and extended. The amount of jitter that is used before a message is transmitted in a time slot is dependent on the range mode and message packing, less jitter being applied for extended range and no jitter being applied for packed two double pulse and packed four. The navigating terminal will know the message packing used. It is obvious from the received message. But nothing in the message tells the navigating terminal with what range mode the PPLI was transmitted. So the terminal will assume that it was transmitted with the same range mode it is using itself. This requires all terminals in a network to be using the same range mode, otherwise TOA measurements will lead to incorrect range estimates.

Range mode is selected by the network designer when a network is designed and the selection parameter is distributed as part of the initialization data sets which instruct the terminals how to behave in the network. Some platforms permit the communication operator to alter range mode. This is only to support a coordinated network change. Individual platforms should not change range mode for their own perceived purposes. If they do, navigation problems can occur. We'll treat this under network troubleshooting.

In order to estimate position in all axes (i.e., latitude, longitude and altitude) the range estimates will require independent information on all three axes. In general, this would require at least three sources, one for each axis. But for aircraft applications, the vertical position is fairly well known by the INS from a blend of inertial information and barometric altitude[10]. So two sources are sufficient for good latitude and longitude. However, this is only true for navigating platforms which have a high time quality based on the active

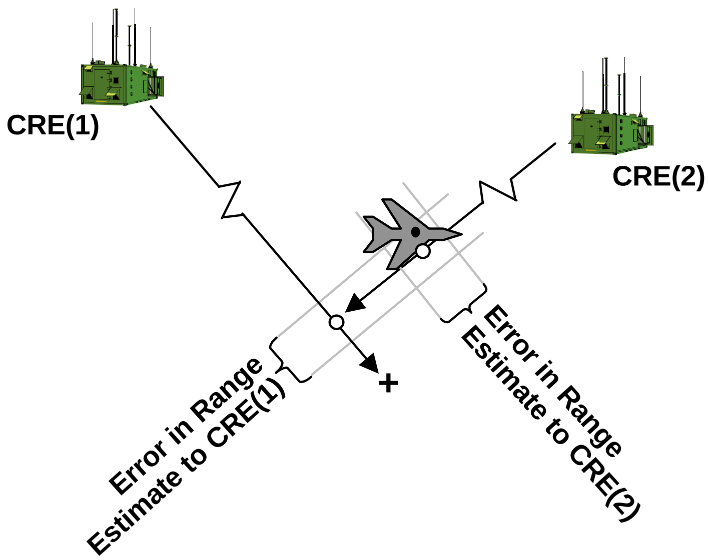
[9] At the time of TOA processing, the error estimate is based, in part, on the Pq and Tq of the source. After TOA processing is complete and until another source is heard from, the estimated error will increase based, in part, on an estimate of the inertial drift also being made during successive TOA processing.
[10] The INS uses barometric altitude to assist the vertical axis of the INS. This is standard practice for aircraft.



9.2-4 Navigation – Geodetic Navigation

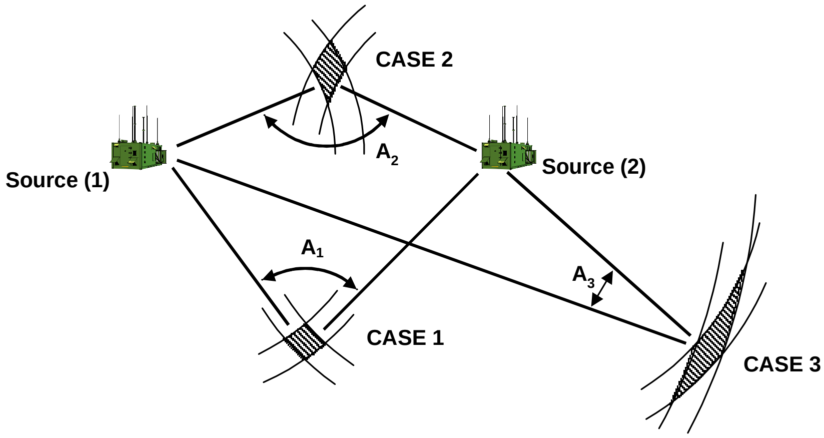
exchange of RTTs. <u>If passive synchronization is being used by the navigating platform (i.e., the F-15 is radio silent), then an additional independent source is required to provide for a good estimate of network time.</u>

The requirement for sources will be discussed further subsequently. It will be found that a single source can look like two sources to a moving aircraft. But before discussing that, the effect of range estimation errors must be discussed a bit.



9.3 Navigation – Geodetic Navigation Errors

Most any two sources located some distance apart will provide independent latitude and longitude information. However, the geometry of the sources relative to the navigating terminal influences the range estimation errors, and it is important that the operators understand this relationship. To examine this issue it is convenient to look at the situation in which PPLIs are received from two high quality sources in rapid succession. This removes the movement of the navigating terminal from the picture. The figure depicts range estimation error bounds for the two sources. The jogs in PPLI propagation paths from each source are intended to show that the distance of the aircraft from each source is much larger relative to the size of the errors than can be shown in the scale of the figure. The actual position of the aircraft will fall within the bounds about the estimate with a high probability. Therefore, the aircraft position will fall within the intersection of the two radii about CRE(1) which represents its TOA range estimation error bounds, and the two radii about CRE(2) which represents its TOA range estimation error bound. In general, the resulting estimate will lie at the center of the volume formed by the intersection of the four radii, and the true position will lie somewhere inside this volume with high probability. In the figure, the lines from the fighter to the sources intersect at almost a right angle and so the error volume is nearly a box. <u>A right angle intersection resulting in an error volume which is a box is the most favorable location for two sources</u>. We'll illustrate this next.



9.4-1 Navigation – Geometric Dilution of Precision (GDOP)

The effect of source location is depicted in the figure. As previously stated, the best case is case 1 where the lines between the navigating terminal and the sources lie at right angles with the error volume being a box. As the angle of intersection becomes more obtuse (e.g., case 2) or acute (e.g., case 3) one axis of the error volume begins to get large which means the position error in that direction will get large. The increase in the error of the position estimate over the best case (i.e., the box which occurs with a right angle) is called geometric dilution of precision (GDOP).

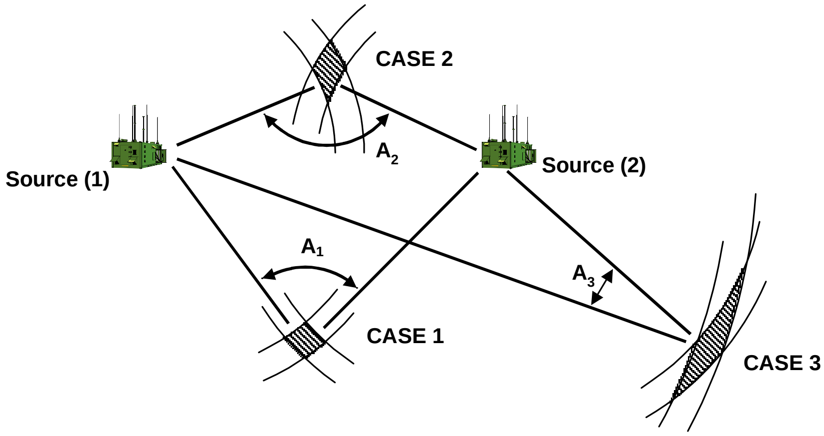
The quantitative impact of GDOP is depicted below. For example, if two sources are

A, degrees	GDOP	A, degrees	GDOP
5 or 175	16.3	25 or 155	3.3
10 or 170	8.1	30 or 150	2.7
15 or 165	5.4	50 or 130	1.7
20 or 160	4.1	90	1.0

located 50 nm apart, a fighter which is located 35 nm from each source will be most favorably located[11]. Suppose the sources are the best quality possible, a position quality (Pq) of 15. Since, in our example, the source qualities are 15, we will assume the navigating terminal's internal Pq is 14 and its reported Pq is 13 (a standard deviation of less than 100 ft). If the fighter moves away from the sources so it is now 150 nm from each source, the angle A is 19.2°[12], the GDOP is about 4.1, the error bound increases from 100 to 410 ft (i.e., 4.1 x 100 ft) and the resulting reported Pq is 8 (the error can be > 400 ft but ≤ 565 ft).

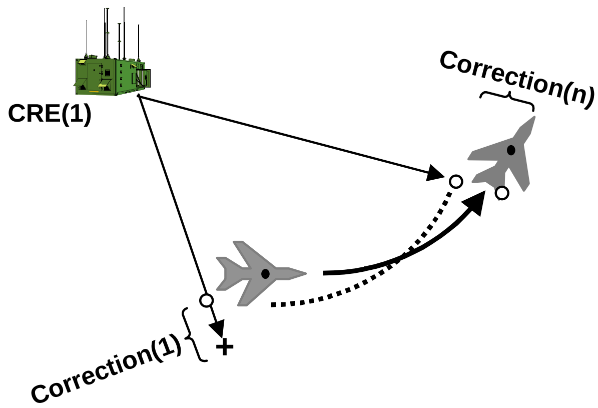
<u>The terminal will use any source with a Pq better than its own to improve its navigation estimate and a network with many participants can help reduce the effect of GDOP</u>. Suppose in the figure we had a fighter at the location of case 1 and a fighter at the location of case 3. While the second fighter is located poorly with respect to the two ground sources, the first fighter is well located and so will have a high Pq, and the second fighter is

[11] 2Arcsin[(50/2)/35]=90°
[12] 2Arcsin[(50/2)/150]



9.4-2 Navigation – Geometric Dilution of Precision (GDOP)

well located with respect to the first fighter and the second ground source, so it will obtain a high quality from them. When multiple sources are available, the terminal automatically selects the best combination of sources to use, based on the geometries and the source qualities.

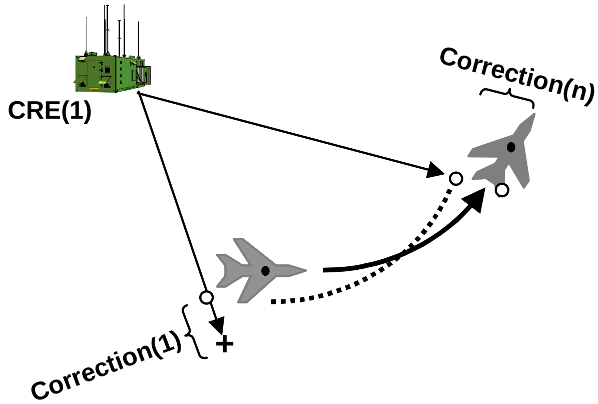


9.5-1 Navigation – Geodetic Sources

A single participant can look like multiple sources to a moving aircraft (see figure). The navigating terminal receives PPLIs from the source as it flies about the source. In this example, south of the source the navigating terminal will make largely latitudinal corrections and east of the source it will make largely longitudinal corrections. As it flies from one orientation to the other the model will use the inertial velocity to move along its position estimate (see the dashed line in the figure). How well the navigating terminal can estimate its position will depend on how fast it moves from one orientation to another relative to the drift rate of its INS since, via the velocity information, the INS is basically "remembering" the corrections at one orientation as the aircraft flies to another. How fast is in terms of the change in the angle of the orientation of the aircraft to the source, the larger the angle the less the effect of GDOP. So how well the aircraft does will depend on how far from the source it is, since that effects how fast it can achieve a large angular change.

Ground platforms do not have to interface a GPS receiver with their terminal to make effective use of its high position quality. They can use a hand-held GPS receiver to find their position and then manually enter it into their terminal along with an estimate of its uncertainty. Their terminal will report that position in its PPLI with a position quality consistent with the entered position uncertainty. Aircraft which are equipped with GPS can also use GPS to improve their JTIDS navigation, but the GPS information must be steadily sent to the terminal. This requires a GPS interface of some sort[13]. The model continues to operate on the inertial velocity input just as before except, every so often (e.g., every 8 seconds), the terminal will be provided a GPS based position fix[14] along with an estimate of it's the fix's position quality. The terminal will use this much as it does a TOA from a PPLI except that it is better since it contains information on all axes and it's normally of very high quality[15]. This will allow the terminal to achieve a very accurate position estimate and report a very high quality PPLI, possibly the highest. Thus, an airborne terminal with GPS inputs can become a very good source for other JTIDS terminals that do not have GPS inputs. This is of great help to the F-15s. Unfortunately not all Air Force platforms send their GPS

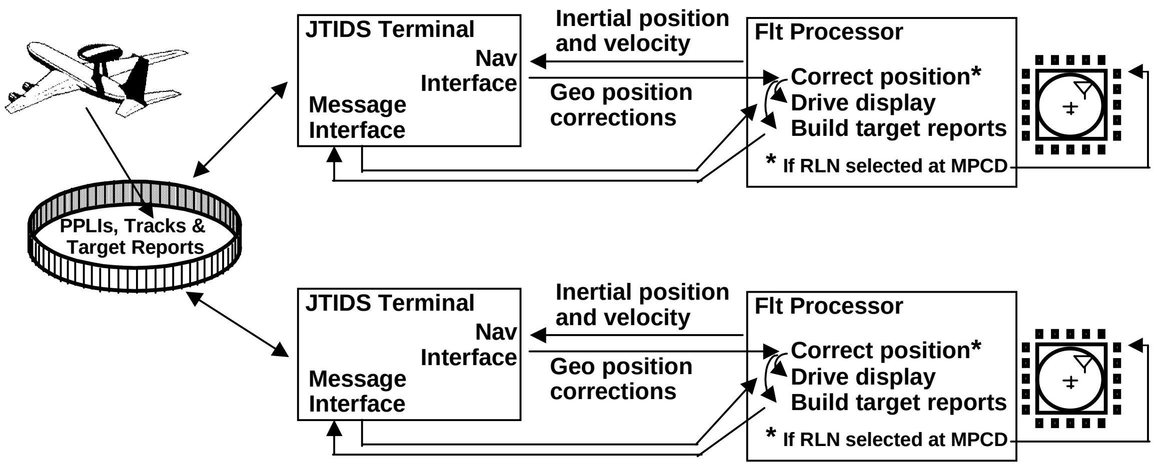
[13] Either direct or via the flight processor.
[14] It can be a fix based on a combination of inertial and GPS information.
[15] TOAs will not normally be processed with GPS fix inputs unless the GPS quality should drop.



9.5-2 Navigation – Geodetic Sources

information to their terminal. The block 30/35 E-3s do. The block 20/25 E-3s[16] and Rivet Joints do not, but Rivet Joint will begin sending GPS information to the terminal in their next software release due in late CY 99[17]. Adding GPS quality to the Rivet Joint along with the fielding of JTIDS to the CRC/CREs will provide a better set of high quality geodetic navigation sources than have been available[18].

[16] Actually, the JTIDS Class 1 terminal in the block 20/25 E-3s has no navigation capability at all. PPLIs from the block 20/25 E-3s normally have a position quality of 3, commensurate with their INS accuracy.
[17] With the TADIL J Upgrade (TJU) JSTARS will send GPS information to the terminal, but it is done in a manner which leads to a relatively low Pq, about 7. So it is of minimal use to the F-15Cs.
[18] F-15Es and F-16s will also have GPS inputs to their terminals providing high geodetic position quality PPLIs.

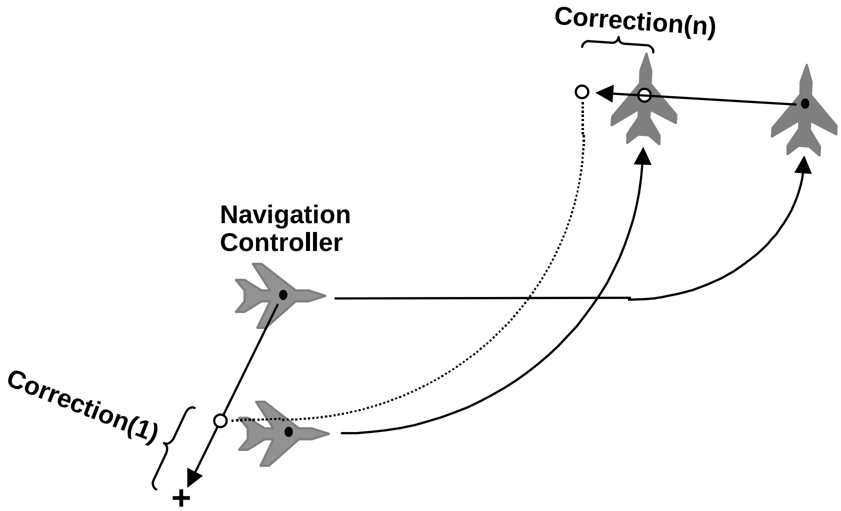


9.6 Navigation – F-15C Use of JTIDS Geodetic Navigation

The F-15 sends inertial position and velocity to its terminal and receives geodetic position corrections based on the terminal's JTIDS navigation function (see figure). The F-15C flight processor[19] applies the corrections to its ownship location, if RLN is selected via the associated button on the MPCD[20]. It uses its corrected position to drive the MPCD (e.g., will subtract its corrected position to display a received PPLI, track or target with respect to its own location) and to build its target reports (i.e., it will add its corrected position to its targets as located by its radar relative to ownship location to create the absolute geodetic location contained in the target reports).

The E-3 and the Rivet Joint do not use the geodetic corrections[21]. The block 30/35 E-3 and Rivet Joint both have GPS integrated with their inertial system which provides their flight processors with high quality position. Therefore, they did not consider use of JTIDS navigation corrections in their flight processors to be a requirement. If the F-15C's geodetic navigation is producing a high position quality, the track errors due to navigation errors for tracks from block 30/35 E-3s and Rivet Joint should be small[22]. The block 20/25 E-3 with its Class 1 terminal does not have a JTIDS navigation capability at all. The block 20/25 tracks are reported using a location estimate based on its INS with an occasional manual update (e.g., via TACAN). This can add a mile or more of location error to their tracks. If the F-15Cs are operating only with the 20/25 E-3 so there are no geodetic sources, the display of its tracks relative to ownship will also contain the F-15C's inertial navigation errors.

[19] The F-15E will use geodetic navigation corrections from its terminal only as a backup to GPS.
[20] This is the recommended mode of operation unless JTIDS navigation is not working properly.
[21] Neither does JSTARS.
[22] Undiscernable on the small 5″ MPCD.

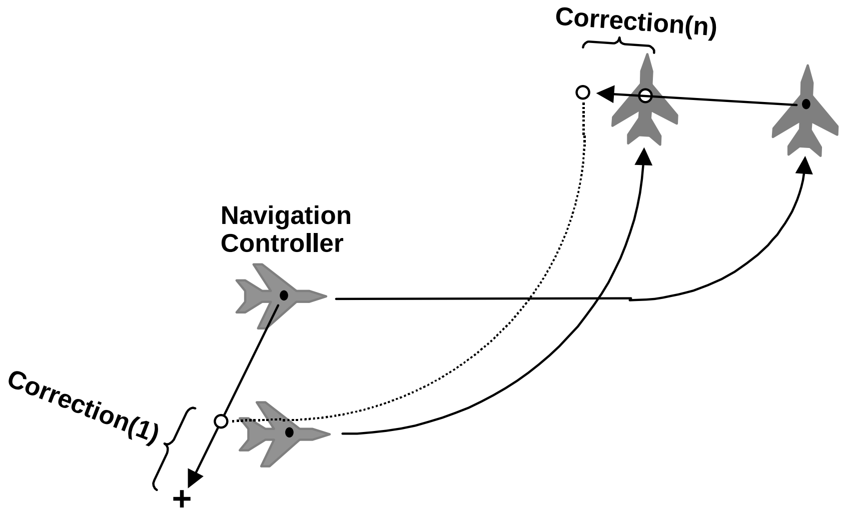


9.7-1 Navigation – Relative Grid Navigation

How does the F-15C make effective use of Link 16 when there are no good geodetic sources available? This can occur if the GPS on the potential sources is being jammed, the fighters are in a location with very poor GDOP, the fighters are operating as an autonomous flight or package, or the fighters are operating only with a block 20/25 E-3. The latter two cases were the norm when JTIDS was introduced to the F-15Cs at Mt Home AFB. To cope with this situation the F-15Cs[23] utilize a second JTIDS navigation mode termed relative grid navigation. In this document we will call it relgrid navigation for short.

Geodetic navigation is always operating in the JTIDS/MIDS terminal. Relgrid navigation is a second mode which operates in parallel with geodetic navigation, but only if it is activated. We'll explain how it is activated in a moment. With relgrid navigation active, one participant, and only one participant[24], is designated navigation controller (NC). For the F-15C this can be done either at the AFMSS or via the MPCD. There is a separate relgrid position reported in the PPLI and a separate relative position quality[25] (RPq) too. The RPq of the NC is transmitted with the highest value, a 15. The other terminals, whose relgrid navigation mode has been activated, estimate their relgrid position relative to the NC's relgrid position. For the fighter application the NC's relgrid position is normally its inertial position[26], so the relgrid position estimate of the non-NC fighters basically takes on the inertial errors of the NC. The fighters can thus know each other's position relative to each other very accurately (assuming high RPqs). This is all that is required to use the PPLIs for interfighter separation and to perform correlation of fighter targets for display. However, pilots using relgrid navigation must be aware that they will have geodetic errors

[23] The F-15Es have GPS and so will not implement the use of relgrid navigation. They will implement the use of geodetic navigation in case their GPS fails since it will permit them to derive GPS quality position from their fellow F-15Es.
[24] In the entire network.
[25] RPq is defined just like the Pq.
[26] This assumes that there are no good geodetic sources and so the geodetic position estimate of the NC's terminal is simply the integration of the NC's inertial velocities.



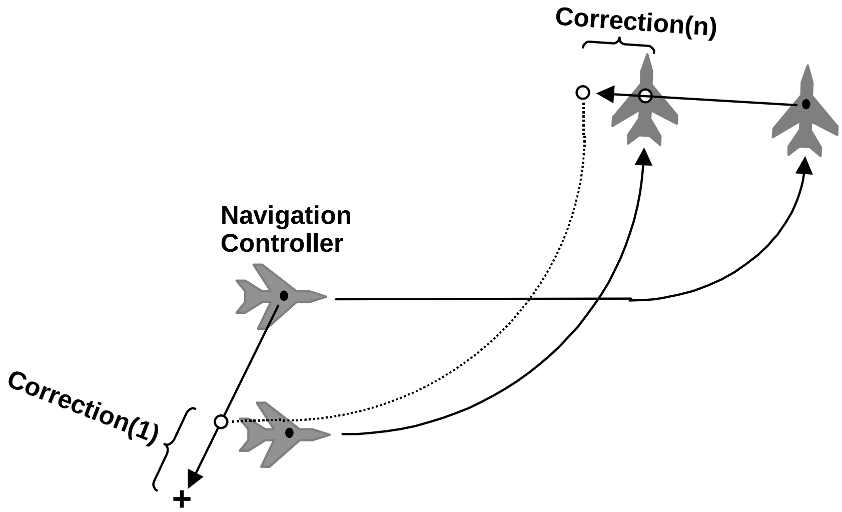
9.7-2 Navigation – Relative Grid Navigation

approximately equal to the inertial errors of the NC, and that absolute geodetic position is still important for locating the fighters with respect to earth fixed reference lines and tracks (e.g., tracks with high absolute geodetic accuracy will be displayed on the MPCD with the inertial errors of the NC). Since the non-NCs will take on the inertial errors of the NC it is wise to select the F-15C with the best INS as NC. At least try not to select a fighter with a particularly poor INS as NC. If the NC's INS goes bad during a mission, that aircraft should give up the NC role and another aircraft should take over as NC; this can be done by the pilots, so long as they take care to insure there are not two NCs operating at the same time.

As with the case where a single source is used for geodetic navigation, use of relgrid navigation requires relative movement of the navigating terminal relative to the NC. If the fighters are close together, for example a flight, this will make quick angle changes simple and they will often be experienced naturally with standard tactics. For example, a standard tactical turn is depicted in the figure. While travelling east the navigating terminal can correct in the southerly direction and after turning north it can correct in the easterly direction. For a fighter element thus flying along easterly for a long time, the non-NC will see[27] its RPq drop off due to the increasing error in the easterly direction. After making a turn to the north, the non-NC will see its RPq jump up as the corrections in the easterly direction take place.

Pilots should monitor their RPqs via the MPCD. Fixed formation flying will not maintain good RPqs. Relative angular movement about the NC is required occasionally by at least one flight member when the RPqs sag to unacceptable levels. If at least one flight member thus improves his RPq, then other flight members may have good GDOP with respect to the NC and that one flight member. Standard tactical maneuvers such as the turn illustrated above can be used and may naturally preclude the need for special maneuvers just

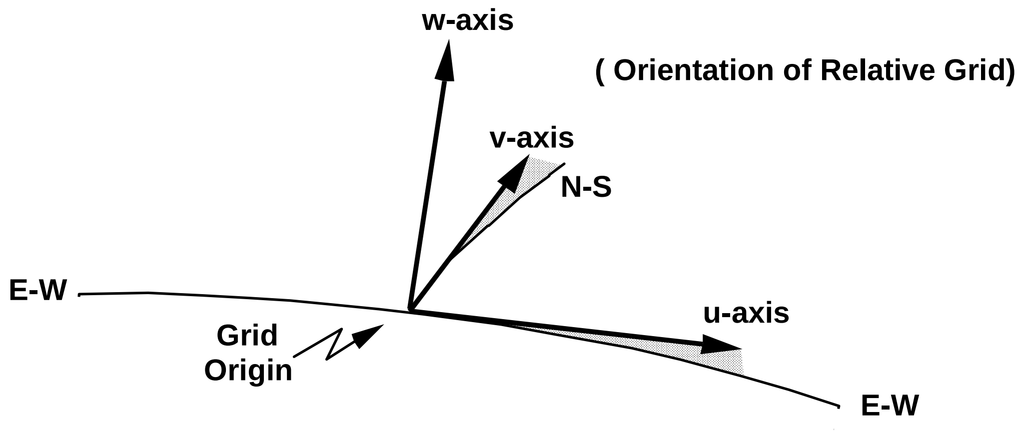
[27] Pq (if using geodetic navigation) or RPq (if using relgrid navigation) is displayed in the upper left hand corner of the MPCD.



9.7-3 Navigation – Relative Grid Navigation

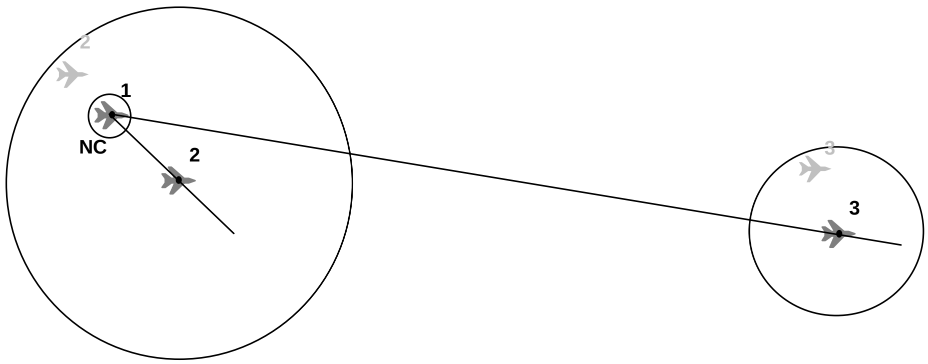
to improve RPq. In fact it is not even necessary to turn. If the aircraft are flying in the same direction for a long time one or more aircraft can drop back or move forward relative to the NC without turning, and that will change the geometry.

It is hoped that as more platforms become available as high quality geodetic sources, the need for relgrid navigation will diminish and the need to take special steps to maintain high navigation quality will abate.



9.8 Navigation – Relgrid Origin

Relative grid navigation is performed in a rectilinear coordinate system whose origin is located anywhere on the surface of the earth with the u-axis pointed east, the v-axis pointed north and the w-axis pointed up. All relgrid participants in the network must enter the same relgrid origin (in latitude, longitude coordinates). The u,v,w coordinate system is used internally by the terminal and in PPLI messages exchanged between terminals. However, the terminal always converts relgrid positions from u,v,w to relative latitude, longitude, and altitude before reporting them to the flight processor. Thus, a flight processor which is using relgrid navigation uses relative latitude and longitude information from the terminal in the same way that it would use geodetic latitude and longitude from the terminal when operating in the geodetic navigation mode; the flight processor never deals with the u,v,w system. The location of the relgrid origin is somewhat arbitrary except that the PPLIs only provide for the reporting of relgrid position within 1000 nm of the origin. If using relgrid in a local area, a central location is recommended to support the widest movement within the area. If using relgrid to fly cross country, an origin displaced in the direction of flight by something just less than 1000 nm will provide relgrid for a trip or flight segment of about 2000 nm. For the F15C, relgrid origin is entered only at the AFMSS. Its entry from the cockpit is not supported.



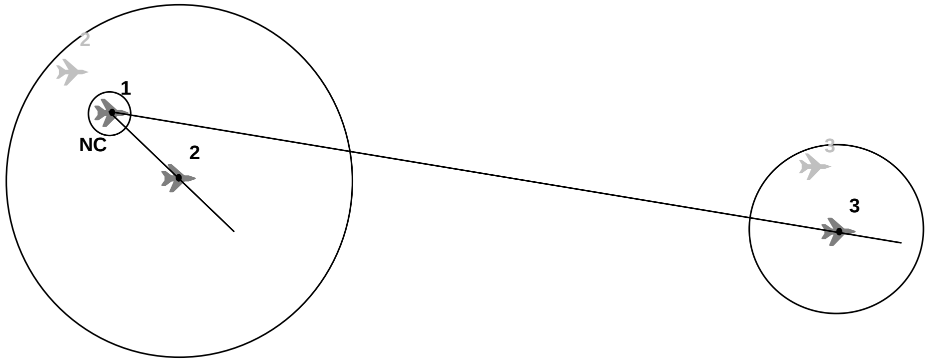
9.9-1 Navigation – Starting Relgrid Navigation Up

To start up relgrid navigation, participants must enter a valid and coordinated relgrid origin. A platform not entering a relgrid origin is equivalent to making relgrid navigation inactive for that platform. In addition, one, and only one, participant must designate himself navigation controller (NC). Once these two steps have been taken, non-NC terminals with a valid relgrid origin will start up relgrid navigation using the NC as their navigation reference.

Relgrid navigation begins for a non-NC terminal with a two-step process. The first is termed grid acquisition during which the terminal obtains the grid origin from a relgrid participant who is already navigating and compares it with their own to check its validity[28]. Grid acquisition permits the transmission of relgrid position via PPLIs, so that an F-15C will see the location of other participants who have successfully acquired the grid on its MPCD (in general, during relgrid operations, the F-15C MPCD will only display received PPLIs that contain relative position; a PPLI which contains only geodetic position will not be displayed[29]). Grid acquisition also enables the processing of TOAs (i.e., the actual navigation process) to begin, but some additional conditions must also be satisfied before this can occur, as will be explained shortly.

Grid acquisition enables the navigating terminal to estimate its initial relative position quality (RPq). We'll explain just how in a moment. The processing of TOAs in order to navigate and improve the RPq is dependent on the relgrid position error of the navigating terminal, the RPq of the relgrid source and the estimated distance between the two[30]. We use the figure to illustrate why. The relgrid position error of each fighter is shown as a circular error bound around its symbol, the dark symbol representing where each fighter thinks it is located. The smaller the bound, the lower the relgrid position error (i.e., the higher the RPq). In the figure, flight position 2 (FP#2) will not process TOAs from the FP#1 because their error bounds overlap and their relative errors are considered too large to establish the direction of a line along which to apply the position correction with sufficient

[28] This is by no means a complete explanation of grid acquisition, nor is this description a complete treatment of relgrid navigation in general. Relgrid navigation is a complex topic whose description is well beyond the scope of this document.
[29] There is an exception to this rule for airborne C^2 platforms, and it will be described subsequently.
[30] 2 (σ source relgrid position error + σ navigator relgrid position error) < separation distance



9.9-2 Navigation –Starting Relgrid Navigation Up

accuracy. Notice that FP#2's true position (which is somewhere inside the largest circle) could be located anywhere around the NC including the other side of it as shown with the light gray symbol. However, FP#3, with its smaller relgrid position error and increased separation, will have an estimated line of correction which is at least in the right general direction. This is required for the proper calculation of corrections.

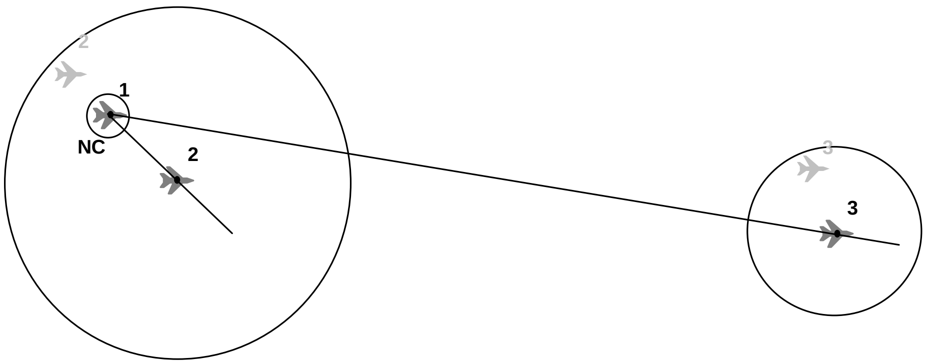
When relgrid navigation first starts up, no TOAs will be processed until at least one participant is far enough from the NC with an adequate relgrid position quality. This participant, once it begins to process TOAs and improve its own RPq, may then be far enough away from and have sufficiently high RPq to support TOA processing by other participants. For example, in the figure FP#3 would start to navigate on the NC and then FP#2 would start to process TOAs from FP#3. If the navigating terminal's relgrid position error is large and its source's RPq is low, the separation between the navigating participant and the source must be large, larger than normal for fighters on the ramp preparing to depart. Thus, F-15C pilots will normally not see an improvement in their RPq while they are on the ramp or even taxiing to take off. The relationship between the displayed RPq of a navigating F-15C and the distance it must be from the NC[31] is given below. At issue is what the fighter's RPq will be when it is starting up relgrid navigation.

Displayed RPq	Range of Rqd Separation, nm	Displayed RPq	Range of Rqd Separation, nm
0[32]	6.0+ (1)	2	0.8-1.5
0[33]	3.0-6.0	3	0.5-0.8
1	1.5-3.0	4	0.4-0.5

(1) This will increase from 6.0 nm the longer the terminal is at a RPq of 0.

When a flight of fighters first start up relgrid navigation on the ramp, and one of the fighters is the NC[34], the other fighters will acquire the grid from the NC and estimate their

[31] If the source is not the NC the distance must be greater, according to the RPq of the source.
[32] After internal RPq has fallen to 0
[33] With internal RPq=1
[34] If there is another flight already using relgrid in the network that the flight is entering, the NC may be in that other flight. If that flight is already airborne and away from the airfield, the flight on the ramp can acquire the grid from any of the other flight members and will likely begin TOA processing immediately since they will be relatively far away.

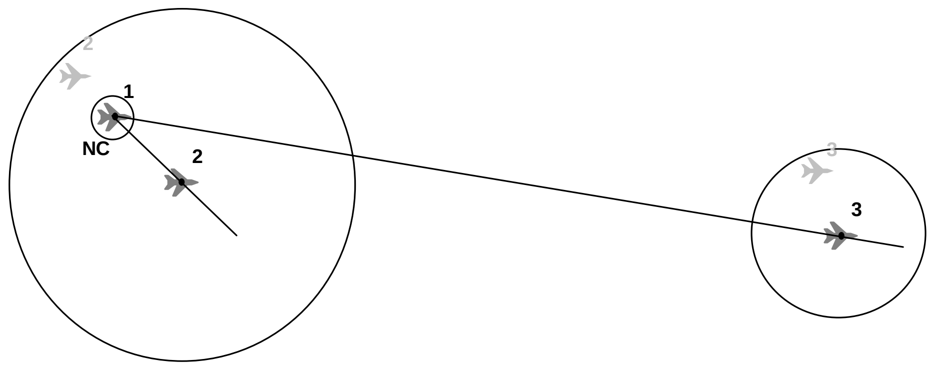


9.9-3 Navigation – Starting Relgrid Navigation Up

initial relgrid position error. Their estimate is based upon the NC's[35] geodetic position quality (Pq) and their own geodetic position error[36]. The geodetic position error estimate is first established when each fighter aligns its INS. If the grid is acquired shortly after that[37], it will normally show an initial RPq of 4. It will drop quite rapidly, more rapidly than the drift rate of the INS alone would warrant, to guarantee that the error in the reported position is less than indicated by the reported RPq. If the flight is on the ramp for a while, ownship RPq may drop to 0. If the flight is forced for some reason to stay on the ramp for an extended time awaiting departure, its ownship relgrid position error will continue to increase, further increasing the separation required to process TOAs. Once having departed the base, the relgrid position error estimates of the non-NC flight members may be so low that the separation distance required to start TOA processing is larger than would be experienced by the flight members during normal tactics (e.g., 6 nm or more, if the RPq has dropped to 0). One solution is to have at least one member of the flight move off in range far enough to enable TOA processing and the commensurate increase in RPqs. However, there are steps the pilots can take before takeoff to improve this situation.

If a non-NC pilot has been on the ramp for a while and he sees that his RPq has fallen to 0, he can perform an INS realignment or a visual update reducing his own geodetic position error. If this could result in an improved RPq[38], the terminal will automatically perform a grid reacquisition and the pilot will see his RPq jump up. If the realignment or visual update does not result in an RPq jump, it may be that the geodetic navigation error of the NC is too big to allow an improvement (the non-NC terminal will not perform the automatic grid reacquisition in that case). If this happens, the non-NC pilot can ask the NC pilot to do an INS realignment or visual update on his aircraft. This may result in an improvement in the NC's Pq, which may then automatically trigger the non-NC terminal to perform a grid reacquisition and improve its RPq. In fact, this action by the NC pilot could help the entire flight and might make it unnecessary for each flight member to do it. Thus,

[35] In some instances (see the footnote above) the fighter will acquire the grid from another fighter which is not the NC. In this case its initial RPq is also a function of the source's RPq. However, if the source is the NC its RPq is 15.
[36] On which the reported Pq is based.
[37] If grid acquisition is much after that, the Pq of the NC as well as the geodetic position accuracy of the acquiring terminal may have dropped sufficiently to result in a lower initial RPq for the acquiring terminal.
[38] This will also depend on the Pq of the NC.

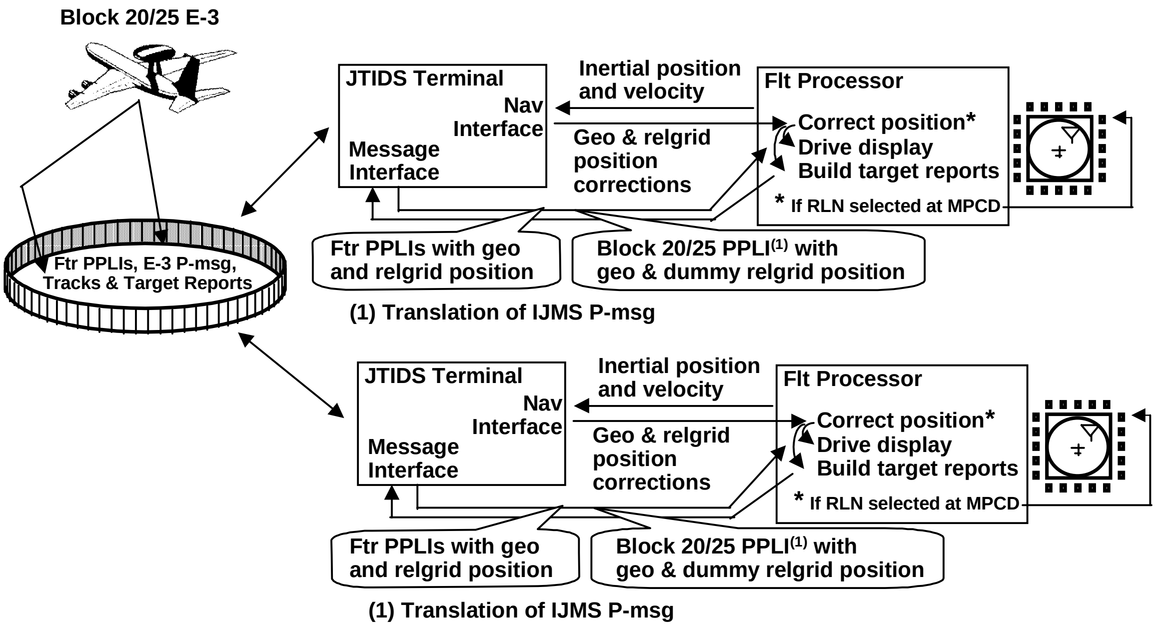


9.9-4 Navigation – Starting Relgrid Navigation Up

having the NC execute an INS realignment or visual update might be the best way to start, if the aircraft are all still on the ground and the non-NC aircraft have noticed that their RPqs have dropped to 1 or 0. If both the NC and the non-NCs must do a realignment or visual update to trigger a grid reacquisition by the non-NC terminals, the order of the two does not matter. Keeping the RPq above 0 with this procedure will ensure that, once airborne, the separation required to start TOA processing (i.e., see RPq increase) is relatively small[39].

Once an aircraft is airborne and navigating, if a non-NC pilot finds it necessary to do a master reset, this will execute a navigation reset and the grid acquisition etc. must all reoccur. The geodetic and hence the initial relative position qualities will be based on the time since the last alignment or INS update was performed, and this could be a long time, resulting in very large geodetic errors and thus very low initial relgrid position qualities after the grid acquisition reoccurs. This would dictate that the fighters be relatively far apart to restart relgrid navigating (e.g., 6 nm or more if RPq is 0). If being far apart at this point in a mission is unacceptable, to reduce the separation required, the NC and then (if necessary) the non-NCs can do a INS update (e.g., a TACAN update) if convenient.

[39] Of course the procedure itself may be more objectionable to the pilots than having to open up the separation after takeoff, so it is simply offered here as a pilot option.

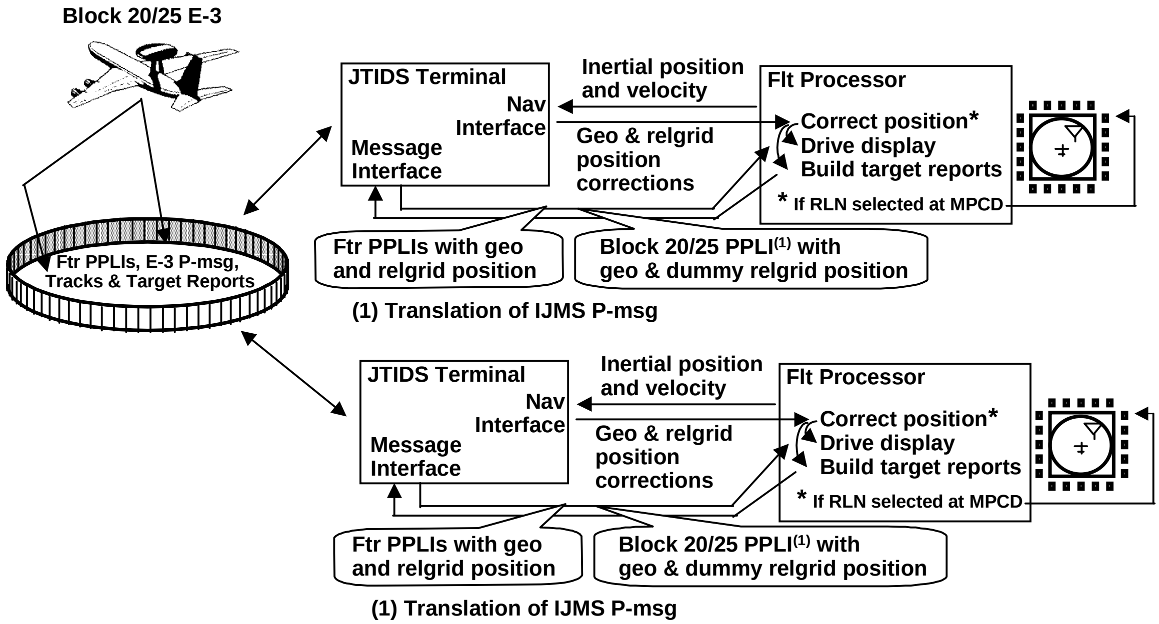


9.10-1 Navigation – F-15C Use of Relgrid Navigation

The first use of relgrid navigation is for autonomous fighter operations. The fighters will coordinate on a relgrid origin and all enter it at the AFMSS. They will also coordinate on a navigation controller (NC) and he will designate himself as such either at the AFMSS or in the cockpit. We suggest the NC be designated only from the cockpit for reasons similar to NTR. We don't want some one using a data transfer module (DTM) with NC designated by accident. Relgrid navigation does not work well with two NCs[40]. Once relgrid navigation is operating, the terminal will send both geodetic and relgrid corrections to the flight processor. Which will be used depends on an initialization parameter in the network design load. We will use network name to tell the pilot how that initialization parameter is set.

The format for the network name has been agreed to internationally as nine alphanumerics. Included in that agreement is that the center alphanumeric is a spare, for national or service use. The Air Force has elected to use the center character to designate how the navigation corrections parameter is set for F-15Cs. The center character is irrelevant to all other platforms. The nominal setting for the center character is "0". All platforms except the F-15Cs will always use a network whose name has a 0 for the central character (e.g., AFBO0013A). For F-15Cs, a 0 in the center character means geodetic navigation will be used (e.g., geodetic navigation corrections will be applied by the flight processor if RLN is selected on the MPCD). As more geodetic sources become available, this should become the normal operation for the F-15Cs. However, if a network can support F-15C operation of either geodetic or relgrid navigation, a version of the network will be posted with a "R" for the center character. This network is for use only by the F-15Cs and is identical to the network with a 0 for the center character except that the use of relgrid navigation has been designated (e.g., the flight processor will use the relgrid corrections if

[40] There is such a thing as a secondary navigation controller (SNC), and this can be selected either at the AFMSS or in the cockpit. It has not been found to be useful for fighter operations and should not be selected. We will not describe its use in this document.

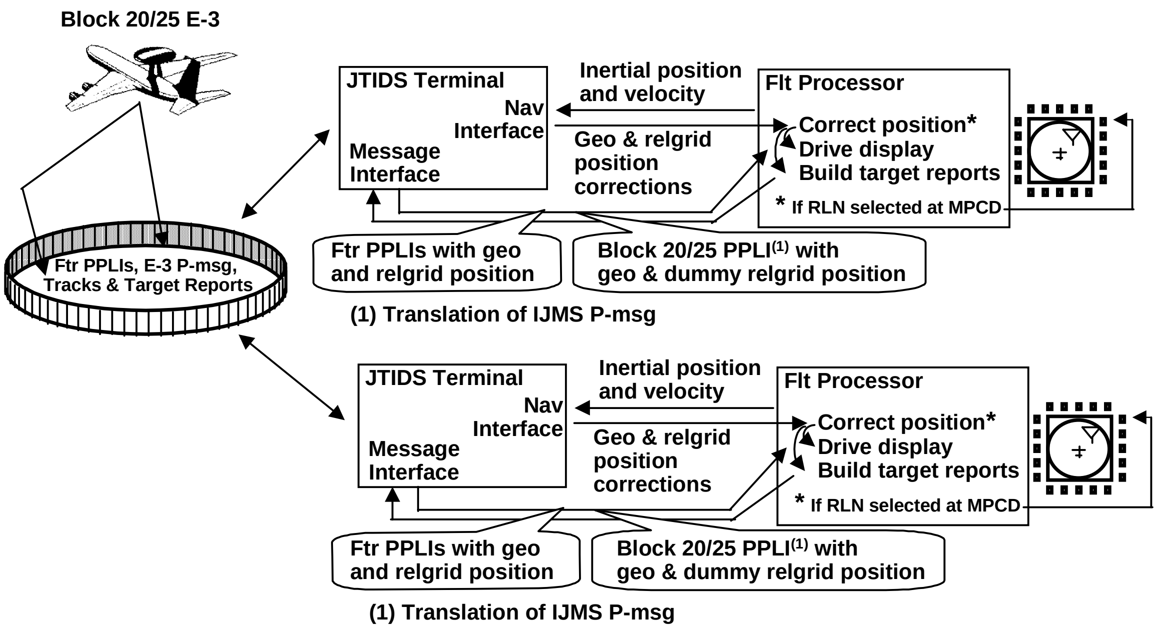


9.10-2 Navigation – F-15C Use of Relgrid Navigation

RLN is selected).

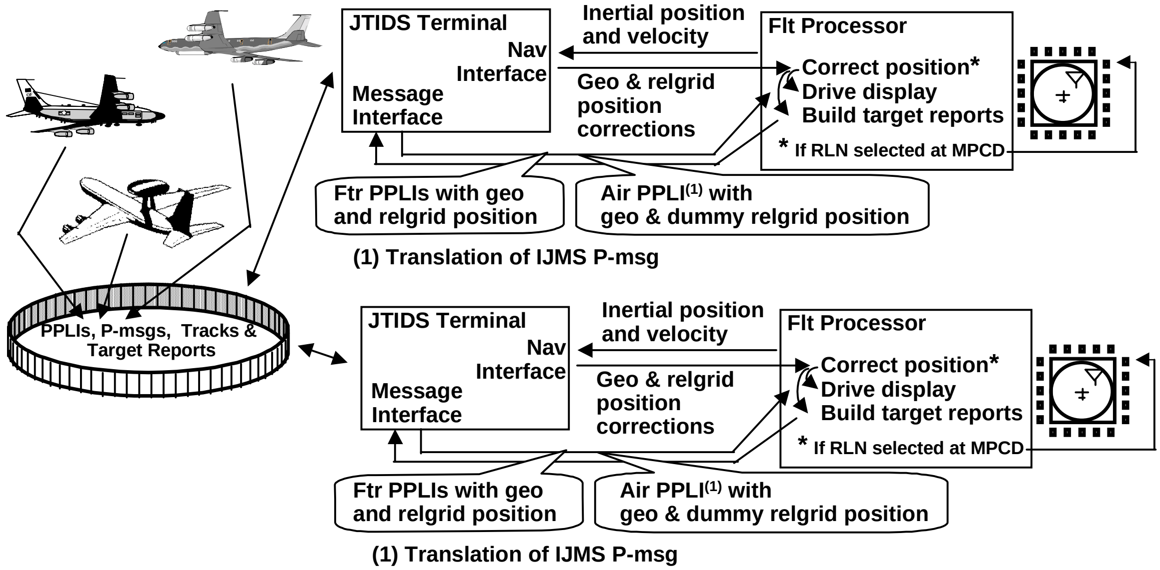
Once operating relgrid navigation the fighter PPLIs will contain relgrid position along with geodetic position. The terminal will send both the geodetic and relgrid position of received PPLI messages to the F-15 flight processor (the relgrid position being converted from u,v,w to relative latitude, longitude, and altitude before it is sent to the flight processor). The navigation parameter (0 or R in the network name) will also dictate which position is used in the F-15's PPLI data base and for display, and which type of position corrections from the terminal will be used by the F-15 flight processor. This works fine for the F-15Cs, but a second reason for using relgrid is because the fighters are working with a block 20/25 E-3. The block 20/25 E-3 is not a good geodetic source, does not have a terminal that performs JTIDS navigation and transmits only an IJMS P-message based on its INS position estimate. The IJMS P-message will arrive at the F-15 terminal and be translated to a TADIL J PPLI before being sent to the flight processor. Normally that PPLI would not include any relgrid position data, and so would not be displayed by the F-15C. However, because it is an air P-message with a source track number (STN) under 200 octal (meaning that it is from a C^2 platform), the terminal will create dummy relgrid data for the PPLI using the geodetic position in the P-message. This way the F-15Cs will see the E-3. However, it will not be seen with relgrid accuracy. <u>The E-3 position will appear on the MPCDs of all the F-15s with a positional error which includes the inertial errors of both the E-3 and the F-15 NC</u>. So while relgrid navigation displays the relative positions of the F-15Cs accurately, the E-3 is not displayed with the same relative accuracy.

Suppose the F-15Cs are working relgrid navigation autonomously or with a block 20/25 E-3 and they are joined by a flight of F-14Ds. If the F-14Ds are not operating relgrid with a coordinated origin, the F-15Cs will not see their PPLIs at all, because there will be no



9.10-3 Navigation – F-15C Use of Relgrid Navigation

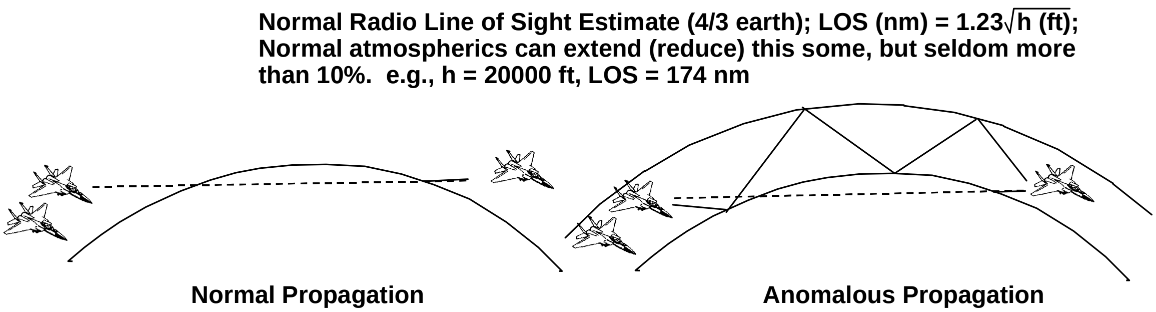
relgrid position data in their PPLIs. So when F-15Cs are using relgrid navigation and they work with other fighters, the other fighters must be operating relgrid navigation with a coordinated origin in order for the F-15Cs to see their PPLIs. Note that the F-15Cs will see the other fighter's radar targets just fine, but with an error which includes the other fighter's navigation error and the inertial error of the F-15 NC.



9.11 Navigation – F-15C Use of Relgrid Navigation with Airborne C^2 Units

Suppose the F-15Cs are operating in an all TADIL J network with a subset of airborne C^2/surveillance units without the block 20/25 E-3, but due to GDOP the F-15Cs cannot achieve a geodetic position whose accuracy is suitable for interfighter use (i.e., fighter separation and target correlation). The F-15Cs may wish to use relgrid navigation. How do they see the PPLIs of the airborne C^2/surveillance units?

One alternative is for the C^2/surveillance units to coordinate on the grid origin and to initialize their terminals to do relgrid with the F-15Cs. The NC would be an F-15C so the F-15Cs would have good GDOP with each other. This would mean that the C^2/surveillance units would not have good GDOP and so would have a relatively poor RPq, but at least the F-15Cs would see their PPLIs. A second alternative is for the C^2/surveillance units to be designed into the network so that they transmit IJMS P-messages along with their PPLIs, even though the network would otherwise not include IJMS at all. Thus, the F-15C terminal would make up dummy relgrid position information on the translated P-message and the F-15C flight processor would display the C^2/surveillance units just as described for the block 20/25 E-3. In this way the C^2/surveillance units need not coordinate on the grid origin (in fact their terminals would not be initialized to use relgrid), and the use of relgrid need only be coordinated among the F-15Cs. This second alternative is being used by the Air Force JTIDS Network Design Facility (AF JNDF) who will add P-message transmissions for C^2/surveillance units, even for all TADIL J networks when a relgrid option for the network is required. So while F-15Cs must coordinate a grid origin with other fighters (e.g., F-14Ds) to see their PPLIs when operating relgrid navigation, they need not coordinate a grid origin with C^2/surveillance units. It is important to note that the C^2/surveillance units should either be initialized to not use relgrid at all, or to use relgrid with the same grid origin as the F-15Cs. If they try to operate in a relgrid but with a different origin than the F-15Cs are using, degradations or anomalous behavior may result.



9.12 Navigation – Effects of Propagation

The effects of propagation anomalies on synchronization were discussed in the synchronization section. The same propagation effects can disrupt the navigation function providing bad TOA measurements resulting in improper position estimates. This is illustrated with an element of F-15s to the rear who have become airborne and are navigating, but who receive PPLIs via ducting from a forward F-15 which is really beyond line of sight. The bad TOAs from the forward F-15 can disrupt the rear F-15s' navigation.

Such anomalous propagation and navigation disruptions have been experienced by F-15s during a deployment to the Persian Gulf. In that area of the world and in the far east, it is not an unusual phenomenon. It effects JTIDS synchronization as well as navigation and is discussed in the synchronization section in more detail. It is a common phenomenon to experienced data link users such as the Navy[41], but was new to the Air Force during the Gulf deployment. During the Gulf deployment it was found that if the F-15s waited until they were above 20000 ft of altitude before entering the network, they were above the layering with its associated ducting. Alternatively, if the fighters detect navigation problems at low altitudes and suspect such propagation effects, they can form their own autonomous network with an offset time to ensure independence from the forward F-15s until they are above 20000 ft and within line of sight of the forward F-15s to join their network and properly navigate.

<u>If operators/pilots experience navigation problems, normal corrective measures do not work, they are operating where atmospherics may be a problem, and they see link performance which seems to defy normal rules for line of sight and the range mode of the network in which they are operating, they should suspect anomalous propagation and, for navigation, can take steps to ensure that they enter a network which does not exhibit such propagation difficulties. For F-15s, it has been found that anomalous propagation effects are not experienced when operating above 20000 ft of altitude[42].</u>

[41] In fact, E-2s have refractometers on board and measure the refractive index on their way up to altitude so they have a good idea of what to expect for data link behavior.
[42] Although this is admittedly based on very limited experience.

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UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
JNETWORK/AFBO0013A/04MAR98/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
JCRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
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9.13 Navigation – OPTASK LINK Message

The OPTASK LINK message is used to coordinate on the grid origin and the navigation controller (NC). The grid origin is coordinated upon using the REFPOINT (point of reference) SETID with a GRIDORG point type . The grid origin can be given a name (the point designation field, field 3) as well as latitude and longitude, each to the minute. In the example, the name is arbitrarily given as ALPHABRAVO and could be programmed into the AFMSS so that the pilot could simply enter the name and receive the stored latitude and longitude. The fourth field is latitude followed by longitude to the minute.

The NC is coordinated upon using the DUTY SETID. In the example we coordinate only to the flight level (e.g., Hogger flight) letting the flight leader select which flight member should be NC. Remember, since the non-NCs take on the inertial errors of the NC it is best to select the fighter with the best INS as NC. At least we want to give the flight leader the option of changing NC if the NC's INS should degrade while in flight.

In garrison responsibilities in support of operations managed by personnel other than at wing:

10. F-15s must decide on which navigation mode will be used. Navigation mode selection is made via network name. A center character of 0 means geodetic navigation and a center character of R means relative grid (relgrid) navigation. The F-15 can store two initialization data sets (termed network design loads (NDLs)) on their data transfer module. Navigation mode is selected independently for each NDL (e.g., the two NDLs can be for the same network, one using geodetic navigation and the other using relgrid navigation). Reference: para 9.10-1

11. Geodetic navigation is always operating in an active terminal. Reference: para 9.5-1

a. Ground units (e.g., the CRC/CRE) can manually enter position and position quality based on a hand held GPS receiver.

b. Aircraft providing only INS data to the terminal (i.e., not GPS based position fixes) exhibit a position quality which rapidly drops to 0 without good geodetic sources. For such platforms (e.g., the F-15C), good geodetic navigation requires high quality sources, good overall time qualities and good GDOP. F-15C unit managers should identify areas with good GDOP so their squadron pilots will know where they can rely on good geodetic navigation.

c. Two high quality sources are sufficient to provide high quality longitude and latitude if the navigating terminal is actively using RTTs for synchronization, otherwise an extra source is required to passively estimate time and position.

d. GDOP can be assisted by other aircraft even if they are providing only INS data to their terminal if the aircraft are well located (i.e., such that they can obtain good geodetic position and then assist other such aircraft to obtain good geodetic position).

e. Airborne platforms can be high (GPS) quality sources if the JTIDS terminal is properly provided GPS based position by the host platform. The block 30/35 E-3 is such an aircraft and the Rivet Joint soon will be (early CY 00).

f. One high quality source can provide longitude and latitude, if the navigating terminal is actively using RTTs for synchronization, with the quality dependent on the magnitude of the arc about the source being traversed (per GDOP), the speed with which it is traversed compared with the drift rate of its INS, and the time qualities.

12. Relgrid navigation must be activated via a relgrid origin and navigation controller (NC). Assume here that only F-15Cs are using relgrid within a network. Reference: para 9.9-1

a. The relgrid origin must be coordinated among all F-15Cs and the same origin entered by all. Relgrid operations are only supported within 1000 nm of the relgrid origin. If using relgrid in a local area, a central location is recommended to support the widest movement within the area. If using relgrid to fly cross country, an origin displaced in the direction of flight by something just less than 1000 nm will provide relgrid for a trip or flight segment of about 2000 nm

b. One, and only one, NC must be designated and so selected by that F-15C. Try to choose the F-15C with the best INS. At least do not choose an F-15C with a bad INS.

c. The non-NC F-15C will take on the INS errors of the NC, and high relative position accuracy.

d. Occasionally, non-NCs must have relative angular movement with respect to the NC to maintain high relative position quality.

9.14-1 Navigation – Wing/Unit Manager Checklist

This checklist is an extension of that started in the Network Management I section. It will be extended in subsequent sections and summarized in Network Management II.

In garrison responsibilities in support of operations managed by personnel other than at wing (continued):

e. Normally, airborne C^2 platforms will be assigned to transmit IJMS P-messages which will supply dummy relgrid position to the F-15Cs. Their PPLIs will be seen with the combined errors of their geodetic error and the NC's inertial errors. This approach is not available for fighters.

f. While the F-15Cs are operating relgrid, any other fighter must be operating relgrid with a coordinated relgrid origin for the F-15C to see its PPLI. This must be negotiated with the network manager of the network in which the F-15Cs are operating. The other (non-F-15C) fighters may or may not be using relgrid navigation corrections themselves. If they are not, their targets will be seen with the combined errors of their geodetic PPLIs and the NC's inertial errors.

13. If operators/pilots experience navigation problems, normal corrective measures do not work, they are operating where atmospherics may be a problem, and they see link performance which seems to defy normal rules for line of sight and the range mode of the network in which they are operating, they should suspect anomalous propagation and, for navigation, can take steps to ensure that they enter a network which does not exhibit such propagation difficulties. For F-15s, it has been found that anomalous propagation effects are not experienced when operating above 20000 ft of altitude. Reference: para 9.12

Network manager responsibilities for daily training network operations:

18. The network manager must decide on which navigation modes will be used, how and by who. Geodetic navigation is always operating in an active terminal. Relgrid navigation must be activated via a relgrid origin and navigation controller (NC). Reference: para 9.13

a. The relgrid origin must be coordinated among all relgrid participants and the same origin entered by all. Use the REFPOINT SET ID of the OPTASKLINK message.

E.g., REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//

b. One, and only one, NC must be designated and so selected by that F-15C. Recommend the network manager assign NC only to flight level permitting the flight leader to designate which F-15C from within the flight. Use the DUTY SETID of the OPTASK LINK message.

E.g., DUTY/390 FS:F-15C:HOGGER/NC//

The NC can designate himself at the AFMSS and/or the cockpit. We recommend that it be done only in the cockpit. A pilot might use a preloaded DTM with NC designated and not be aware of that fact which could lead to two NCs inadvertently being extant in the network.

c. Otherwise, refer to items under the in-garrison checklist

9.14-2 Navigation – Wing/Unit Manager Checklist

9. If using geodetic navigation and low Pqs are experienced it may be that Reference: para 9.2-1

10.

a. There is not a sufficient number of high quality sources, or there are but you are in a low GDOP area or there is but one high quality source and you are not moving so as to traverse a sufficiently large arc about the source fast enough to overcome the drift rate of your INS.

b. You have low time quality (Tq). Tq is not displayed in the F-15C. Low Tq can occur if you are a primary user (the usual F-15C setting for normal range mode networks) and out of range or line of sight of another network participant with a good Tq or if the net time reference (NTR) has left the network and another NTR has not been designated.

c. You are radio silent doing passive synch and there are not sufficient sources to estimate both position and time.

10. If using relgrid navigation and low RPqs are experienced it may be thatReference: para 9.7-2

a. Your RPq is so low and your distance from other relgrid participants so short that your terminal will not start up relgrid navigation i.e., TOA processing. This can be prevented before takeoff by keeping your RPq above 0 with combinations of INS alignment/visual update by your NC and yourself. Once airborne an option is too have one flight member separate from the flight far enough to see the RPqs jump up and then for him to return.

b. You have been in a fixed position with respect to the NC for a long time and you are in an area of poor GDOP regarding other high quality relgrid participants or you have recognized the problem just cited but are not moving so as to traverse a sufficiently large arc about the NC fast enough to overcome the drift rate of your INS.

9.15 Navigation – Network Troubleshooting

10.0 Network Management II

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR
CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

10.1-1 Network Management II – Summary

This section will review the completed example of an OPTASK LINK message. After reviewing the OPTASK LINK we will discuss entry of information derived from the OPTASK LINK and determined at premission brief into the F-15C initialization data sets[1] on the data transfer module (DTM) via the Air Force Mission Support System (AFMSS) since experience indicates that it will likely be the unit manager that sets up the DTMs for the squadron pilots rather than each pilot himself. We then present the completed Wing/Unit Manager Checklist and the completed Troubleshooting Guide. This will complete the main portion of the document with the remaining sections being special topics.

The OPTASK LINK is discussed via each line starting with the first line.

Line 1 – This message is unclassified since it is only an example and contains no real operational information. Operational OPTASK LINK messages are typically confidential or secret. However, units may decide that training networks may be supported by unclassified OPTASK LINK messages which will permit their distribution via e-mail.

Line 2 – This is an OPTASK LINK message which has been created by the 552 ACW and it is the first such message created by them in the month of July.

Line 3 – The period for which the OPTASK LINK holds is from 0800Z on 15 July to 2200Z on 25 July.

Line 4 - This is the start of the Link 16 portion of the OPTASK LINK which may cover other links (e.g., Link 11)

[1] This version of the document does not treat the entry of reference lines. This may be included in a subsequent version as an additional topic.

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR
CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

10.1-2 Network Management II – Summary

Line 5 – The period for which the Link 16 portion of the OPTASK LINK holds is 0800 on 16 July to 2200 on 24 July.

Line 6 – An E-3 from the 964 AWACS with voice call sign Magic is designated to be net time reference (NTR).

Line 7 – If relgrid navigation is to be used, the navigation controller (NC) will be an F-15C drawn from the Hogger flight from the 390 FS.

Line 8 – If relgrid navigation is to be used, the relgrid origin will be at 27° 15´ North and 64° 30´ West and have a reference name of Alphabravo.

Line 9 – The network is AFBO0013A. It is the first (A) version of the 013th operational network owned by the US Air Force and designed by the Air Force JTIDS Network Design Facility (AF JNDF). NDLs for Air Force platforms may have been updated for changes to platform specific parameters since the original network was designed, and the wing/unit managers should so determine for their platforms from the AF JDNF web site.

Line 10 - An E-3 from the 964 AWACS with voice call sign Magic will have a source track number (STN) of 00001, use a network design load (NDL) with participant identifier E3(1), and assign a track number block of 00300-01177 octal. Their TADIL A data link reference number (DLRN) block should match the TN block with values 0300-1177 octal.

If it is a mixed IJMS/TADIL J network, a GENTEXT SETID may indicate their IJMS system reference number (SRN) block should match their TN block and that a IJMS entry will not be made. For example,

UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//

10.1-3 Network Management II – Summary

GENTEXT/FOR MIXED IJMS AND TADIL J OPERATIONS, E-3S SHOULD MATCH THEIR SRN BLOCK AND THEIR REQUIRED TADIL A DLRN BLOCK TO THEIR ASSIGNED TN BLOCK. AN SRN BLOCK HAS NOT BEEN ASSIGNED VIA AN IJMS PORTION OF THE OPTASK LINK.//

If the packing limit for a given network participation group (NPG) is to be manually changed from the values specified in the NDL, the GENTEXT SETID may be used to so indicate. For example,

GENTEXT/964 AWACS:E-3:MAGIC SHOULD CHANGE SURVEILLANCE (NPG 7) PACKING LIMIT FROM 3[2]-PACKED FOUR SINGLE PULSE TO 1-PACKED TWO DOUBLE PULSE TO MINIMIZE OBSERVED MULTIPATH EFFECTS. REDUCTION IN SURVEILLANCE TRANSMIT CAPACITY TO BE ACCOMODATED WITH LENGTHENED TRACK REPORTING INTERVALS.//

Line 11 - The 726 ACS CRC with voice call sign Blueboy will have a source track number (STN) of 00002, use a network design load (NDL) with participant identifier CRC(1), and assign a track number block of 01200-02077 octal. Their TADIL A/B data link reference number (DLRN) block should match the TN block with values 1200-2077 octal.

Line 12 - The 255 ACS CRC with voice call sign Redtop will have a source track number (STN) of 00003, use a network design load (NDL) with participant identifier CRC(2), and assign a track number block of 02100-02777 octal. Their TADIL A/B data link reference number (DLRN) block should match the TN block with values 2100-2777 octal.

[2] Numeric codes for packing limit are utilized (0-standard, 1-packed two double pulse, 2-packed two single pulse, 3- packed four single pulse).

```
UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR
CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//
```

10.1-4 Network Management II – Summary

Line 13 - The 97 IS RC-135 Rivet Joint with voice call sign Vacuum will have a source track number (STN) of 00004, use a network design load (NDL) with participant identifier RJ(1), and assign a track number block of 03000-03277 octal. Their TADIL A data link reference number (DLRN) block should match the TN block with values 3000-3277 octal.

Line 14 – A flight of F-15Cs from the 390 FS with voice call sign Hogger will use STNs 00230-00233 with the flight lead nominally being 00230, and they will use NDLs F15(1.1.1)-F15(1.1.4).

Line 15 – A flight of F-15Cs from the 390 FS with voice call sign Eagle will use STNs 00234-00237 with the flight lead nominally being 00234, and they will use NDLs F15(1.1.5)-F15(1.1.8).

If this was a NATO network the F-15C might get their NATO track numbers via a GENTEXT SETID.

Line 16 – A cryptokey with short title AKAT4421 will be used for cryptovariable logical label (CVLL) 1 and a cryptokey with short title USKAT2102 will be used for CVLL 2.

Line 17 – The control function (NPG 9) will have Magic on net 1, Redtop on net 2 and Blueboy on net 3.

Line 19 – Only voice A (NPG 12) will be used with inter C^2 voice on net 0, Hogger flight on net 1 and Eagle flight on net 2.

Line 20 – All fighters will use the same fighter channel (i.e., non C^2-to-non-C^2 NPG) and it will be net 1.

UNCLAS
MSGID/OPTASK LINK/552 ACW/001/JUL//
PERIOD/150800ZJUL/252200ZJUL//
LNKXVI/16//
PERIOD/160800ZJUL/242200ZJUL//
DUTY/964 AWACS:E-3:MAGIC/NTR//
DUTY/390 FS:F-15C:HOGGER/NC//
REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//
NETWORK/AFBO0013A/-//
JUDATA/964 AWACS:E-3:MAGIC/00001/E3.1/-/-/-/-/-/00300-01177//
JUDATA/726 ACS:CRC:BLUEBOY/00002/CRC.1/-/-/-/-/-/01200-02077//
JUDATA/255 ACS:CRC:REDTOP/00003/CRC.2/-/-/-/-/02100-02777//
JUDATA/97 IS:RC-135:VACUUM/00004/RJ.1/-/-/-/-/-/03000-03277//
JUDATA/390 FS:F-15C:HOGGER/00230-00233/F15.1.1.1-F15.1.1.4/-/-/-/-/-/-/-//
JUDATA/390 FS:F-15C:EAGLE/00234-00237/F15.1.1.5-F15.1.1.8/-/-/-/-/-/-/-//
CRYPDAT/1/AKAT4421/2/USKAT2102//
JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1/REDTOP AIR CNTRL/2/BLUEBOY AIR CNTRL/3//
JSTNETS/VGA/12/C2 VOICE/0/HOGGER VOICE/1/EAGLE VOICE/2//
JSTNETS/NCNC/19/F15 FTR-TO-FTR/1//

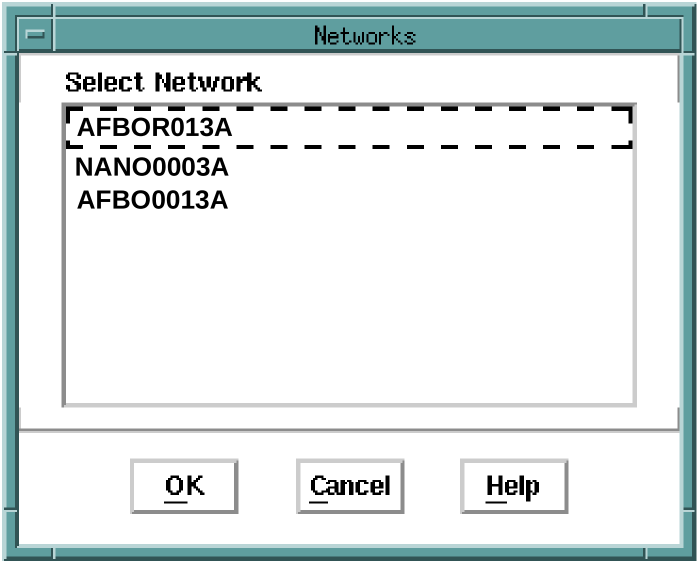
10.1-5 Network Management II – Summary

The network will be assumed to be using a relative time base and Zulu time unless otherwise specified. If an external time reference is to be used, we suggest it be specified in the OPTASK LINK via a GENTEXT SETID. For example,

GENTEXT/NETWORK WILL EMPLOY EXTERNAL TIME REFERENCE USING GPS TIME. PLATFORMS IMPLEMENTING ETR SHOULD ENABLE. ANY NTR MUST BE ETR CAPABLE.//

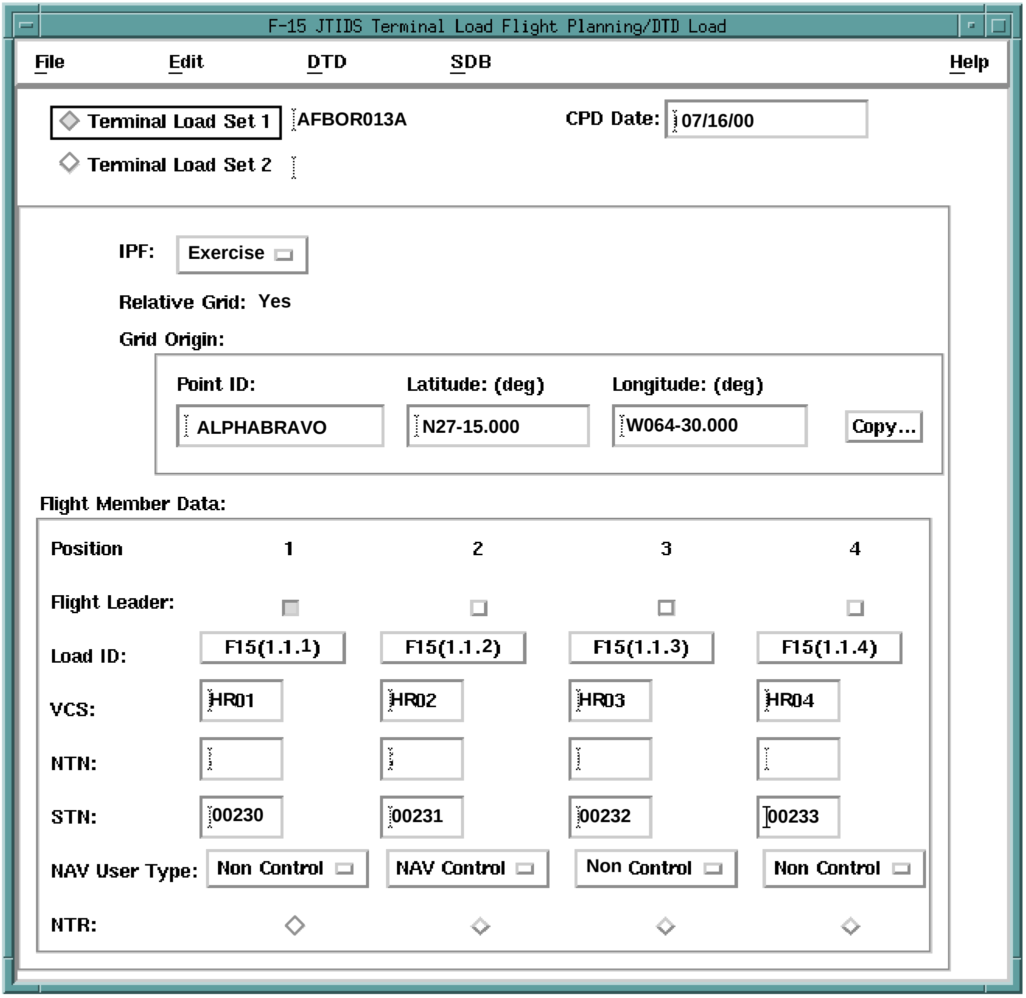
If a relative time base other than Zulu time is to be used, we suggest it be specified in the OPTASK LINK message via the GENTEXT SETID. For example,

GENTEXT/THE LINK 16 NETWORK WILL EMPLOY LOCAL TIME AS THE TIME BASE RATHER THAN THE NORMAL ZULU TIME.//



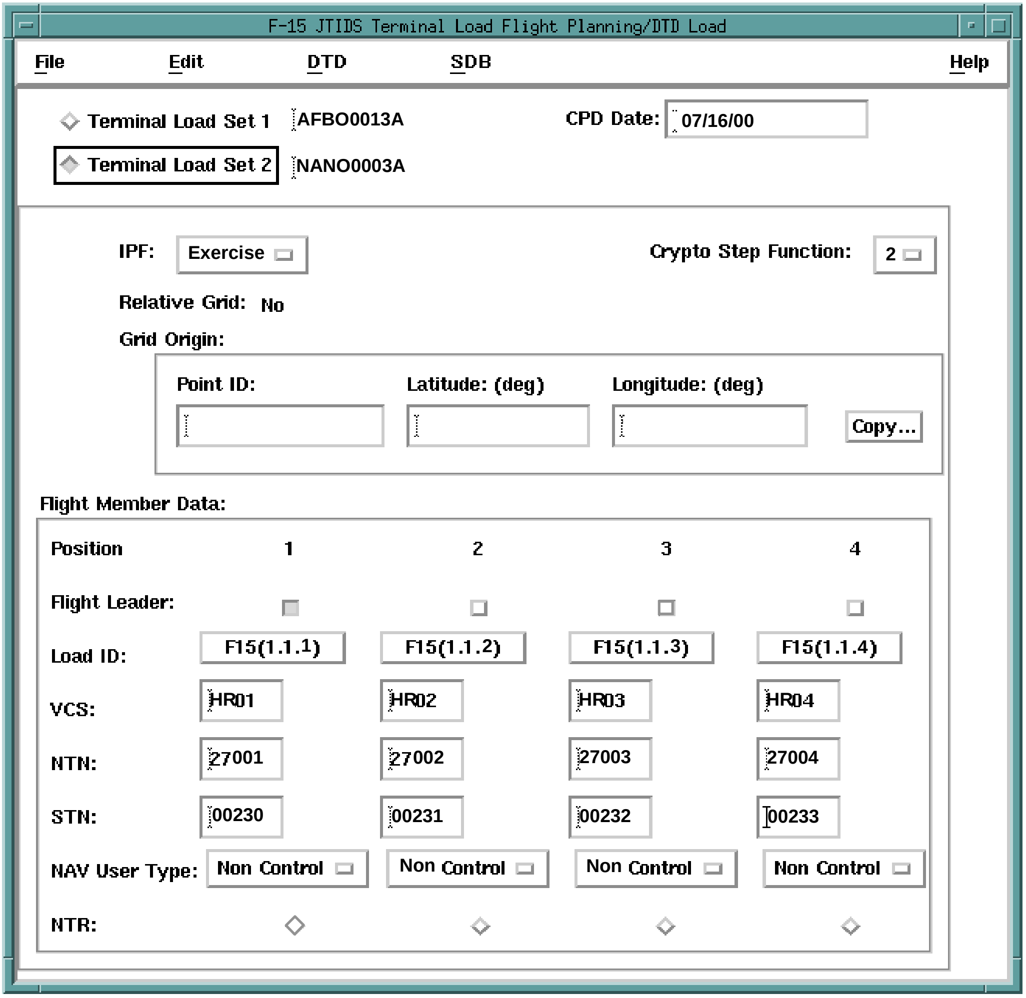
10.2-1 Network Management II – F-15C Initialization Loads via the AFMSS

The complete local JTIDS network library (JNL) should be maintained at each squadron on diskettes, one per network. The AF JNDF web site should be visited weekly to be sure the local JNL is up to date. A subset of the JNL, up to 50 networks, can be kept on the AFMSS. To load one or two initialization loads on the DTM, the operator must first reference the Networks page. In the figure the JNL is limited to two networks with AFBO0013A having both a geodetic and relgrid version, and we have selected AFBOR013A. We then move to the F-15 JTIDS Terminal Load Planning/DTM Load menu.



10.2-2 Network Management II – F-15C Initialization Loads via the AFMSS

Referencing the example OPTASK LINK we set up the DTMs for Hogger flight. We first enter the date for use by the AFMSS in calculating the current cryptoperiod designator (CPD). We will assume that we are loading the DTM on the first day for which the OPTASK LINK is effective, 16 July 2000. The interference protection feature (IPF) is set to exercise in the NDL. This can be changed to Combat, but only with authorization in a full wartime environment. The navigation mode for the NDL is relgrid. (The setting displayed is based on the navigation initialization parameter in the NDL, not the network name.) This is consistent with the network name. The grid origin is per the OPTASK LINK with a reference name Alphabravo. The four flight positions are shown across the bottom half of the menu with 1 being the flight lead. The four participant identifiers (i.e., “Load ID”) in the OPTASK LINK are selected from the network. The voice call signs and source TNs are taken from the OPTASK LINK. There are no NATO TNs for this Air Force network. The OPTASK LINK specifies that the navigation controller be selected from the Hogger flight, and this job has been assigned to Hogger 2. We show Hogger 2 so designated at the AFMSS, however, we have recommended that NC not be designated at the AFMSS, but rather that it designated only from the cockpit to avoid confusion which might lead to multiple NCs. The NTR is the E-3, not an F-15C, so no NTR has been specified.



10.2-3 Network Management II – F-15C Initialization Loads via the AFMSS

Suppose that the F-15Cs may wish to load another network onto the DTM. The operator selects the second network from the Networks menu and receives a menu as shown in this figure. We have no example OPTASK LINK for this network, but we'll review the entries anyway to illustrate some new features. First this NATO network is a geodetic network and no relgrid origin is required. Since this is the second network we are offered the option of stepping the cryptokey so that we can load a different cryptokey from the one being used by the first network. We've assumed for this example that the NATO network is using a different cryptokey and have stepped the cryptokey twice, moving the KGV-8 locations for the NATO cryptokey from locations 6/7 to 2/3. This will require loading cryptokey for NPG 20 into locations 0/1 and 4/5. All other entries are assumed to be the same except we have been given NATO TNs. Remember, while we must enter numerics for the NATO TNs, they will be given to us as two alphabetics followed by three numerics. In this case the flight has been given alphabetics GM001-GM004. The code was given in the track numbering section and is repeated here as A=0, E=1, G=2, H=3, J=4, K=5, L=6 and M=7.

Wing/Unit Manager Checklist

In garrison responsibilities in support of operations managed by personnel other than at wing:

1. Maintain local JTIDS network library (JNL) taken from AF JNDF web site weekly and maintained in a notebook and, if appropriate, on diskette (one network per diskette labeled and dated). Reference: para 4.3
2. If operating in a NATO network involving NADGE sites, wing/unit managers for fighters should be prepared to receive NATO TNs for their fighters and to help make their entry using the appropriate coding for the first two letters. Look for the NATO TNs as part of the GENTEXT SETID of the IJMS or LINKXVI section of the OPTASK LINK, or by telecon. Reference: para 5.4-2
3. Consult the cryptokey utilization plan on the AF JNDF web site and order the cryptokey which is indicated for wing platforms via the base cryptocustodian and normal cryptochannels. At fighter wings, the wing and unit managers should ensure that adequate cryptokey is drawn from wing accounts and held at unit level for daily use. Reference: para 7.11
4. Ensure that cryptokey fill is performed by wing operators in accordance with the OPTASK LINK message and the network cross reference table contained in the associated network description in his local JTIDS network library. Reference: para 7.11
5. Ensure that cryptokey fill operators have sufficient information to load the cryptokey in the correct terminal memory locations and to select the correct location with which to begin operations (i.e., choose the correct current CPD). Reference: para 7.12

Improper cryptokey utilization is one of the primary causes of unsuccessful Link 16 operations including the use of the wrong short title, loading cryptokey into the wrong KGV-8 memory locations and selecting the wrong starting location (i.e., improper date or current CPD)

6. To provide guidance to their operators regarding frequency management, the DOD has published two important documents, the JTIDS/MIDS Spectrum Users Guide and Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 6232.01A. Wing managers should be familiar with these documents. They are posted on the AF JNDF web site. Reference: para 8.1-2
7. Ensure that wing platforms operating in Link 16 networks are doing so under valid frequency assignments. Reference: para 8.2

   a. For deployed operations review the assignment under which wing platforms will operate

   b. Be familiar with Air Force Manual 33-120 entitled Radio Frequency (RF) Spectrum Management which will permit the wing manager to understand the frequency assignments

8. Ensure that wing platforms are operating in accordance with the constraints expressed in the frequency assignment under which they are operating. Constraints regarding: Reference: para 8.17

   a. The distance of his platforms from radionavigation aids and ATCRBS radars

   b. The total TSDF of any operation in which his platforms participate (i.e., deconfliction)

   Note that the combat IPF setting is not authorized for use during normal peacetime operations

9. Ensure that frequency deconfliction is performed for all Link 16 operations in which your platforms take part and that the use of Link 16 by your platforms is scheduled in the deconfliction server data base. Reference: para 8.12

   a. The wing manager should query the deployed operations manager to satisfy himself that the frequency management responsibilities are being properly carried out including the posting of the operation on the deconfliction server, particularly with respect to his participating platforms.

Operating JTIDS/Link 16 with the procedures and within the constraints set down by the NTIA and the FAA is critical, and failure to do so can have serious consequences. The DOD operates JTIDS/Link 16 in the radionavigation aids band as a secondary user and will continue to be permitted to share the band only if they operate the data link system properly.

10. F-15s must decide on which navigation mode will be used. Navigation mode selection is made via network name. A center character of 0 means geodetic navigation and a center character of R means relative grid (relgrid) navigation. The F-15 can store two initialization data sets (termed network design loads (NDLs)) on their data transfer module. Navigation mode is selected independently for each NDL (e.g., the two NDLs can be for the same network, one using geodetic navigation and the other using relgrid navigation). Reference: para 9.10-1

11. Geodetic navigation is always operating in an active terminal. Reference: para 9.5-1

    a. Ground units (e.g., the CRC/CRE) can manually enter position and position quality based on a hand held GPS receiver.

    b. Aircraft providing only INS data to the terminal (i.e., not GPS based position fixes) exhibit a position quality which rapidly drops to 0 without good geodetic sources. For such platforms (e.g., the F-15C), good geodetic navigation requires high quality sources, good overall time qualities and good GDOP. F-15C unit managers should identify areas with good GDOP so their squadron pilots will know where they can rely on good geodetic navigation.

    c. Two high quality sources are sufficient to provide high quality longitude and latitude if the navigating terminal is actively using RTTs for synchronization, otherwise an extra source is required to passively estimate time and position.

d. GDOP can be assisted by other aircraft even if they are providing only INS data to their terminal if the aircraft are well located (i.e., so that they can obtain good geodetic position and then assist other such aircraft to obtain good geodetic position.

e. Airborne platforms can be high (GPS) quality sources if the JTIDS terminal is properly provided GPS based position by the host platform. The block 30/35 E-3 is such an aircraft and the Rivet Joint soon will be (early CY 00).

f. One high quality source can provide longitude and latitude if the navigating terminal is actively using RTTs for synchronization with the quality dependent on the magnitude of the arc about the source being traversed (per GDOP), the speed with which it is traversed compared with the drift rate of its INS, and the time qualities.

12. Relgrid navigation must be activated via a relgrid origin and navigation controller (NC). Assume here that only F-15Cs are using relgrid within a network. Reference: para 9.9-1

a. The relgrid origin must be coordinated among all F-15Cs and the same origin entered by all. Relgrid operations are only supported within about 1000 nm of the relgrid origin. If using relgrid in a local area, a central location is recommended to support the widest movement within the area. If using relgrid to fly cross country, an origin displaced in the direction of flight by something just less than 1000 nm will provide relgrid for a trip or flight segment of about 2000 nm

b. One, and only one, NC must be designated and so selected by that F-15C. Try to choose the F-15C with the best INS. At least do not choose an F-15C with a bad INS.

c. The non-NC F-15Cs will take on the INS errors of the NC, and high relative position accuracy.

d. Occasionally, non-NCs must have relative angular movement with respect to the NC to maintain high relative position quality. For example, flying cross country in a fixed formation will result in low RPqs.

e. Normally, airborne C^2 platforms will be assigned to transmit IJMS P-messages which will supply dummy relgrid position to the F-15Cs. Their PPLIs will be seen with the combined errors of their geodetic error and the NC's inertial errors. This approach is not available for fighters.

f. While the F-15C is operating relgrid, any other fighter (e.g., F3 or F-14D) must be operating relgrid with a coordinated relgrid origin for the F-15C to see its PPLI. This must be negotiated with the network manager of the network in which the F-15Cs are operating. The other (non-F-15C) fighters may or may not be using relgrid navigation corrections themselves. If they are not, their targets will be seen with the combined errors of their geodetic PPLIs and the NC's inertial errors.

13. If operators/pilots experience navigation problems, normal corrective measures do not work, they are operating where atmospherics may be a problem, and they see link performance which seems to defy normal rules for line of sight and the range mode of the network in which they are operating, they should suspect anomalous propagation and, for navigation, can take steps to ensure that they enter a network Reference: para9.12

which does not exhibit such propagation difficulties. For F-15s, it has been found that anomalous propagation effects are not experienced when operating above 20000 ft of altitude.

Network manager responsibilities for daily training network operations:

1. If necessary, request Air Force-only training networks from the Air Force JTIDS Network Design Facility (AF JNDF) and joint and allied training networks from the JTIDS Network Design Library (JNDL). Use the form on AF JNDF web site and/or the network request items from this document. Coordinate requests for joint/allied networks with AF JNDF. Reference: para 4.5
2. Select network from Air Force JNL and task individual platforms via NETWORK SETID of the OPTASKLINK. Tasking may be informal, but use of the OPTASK LINK is strongly recommended, where appropriate, to become experienced with its use. Example NETWORK/AFBO0013A/-//. Reference: para 4.11-1
3. Associate individual participants with the appropriate network design load (NDL) via participant identifier in the JUDATA SETID of the OPTASKLINK. Example, 965 AWACS E-3 call sign Magic use NDL for E3(1), i.e., JUDATA/964 AWACS:E-3:MAGIC/-/E3.1/…... Reference: para 4.11-2
4. Define use of stacked nets. Example voice A net 0 for C^2 platform use, net 1 for Hogger flight, net 2 for Eagle flight. Control net 1 for E3(1). Fighter-to-Fighter (F/F) net 1 used by all F-15s. Distribute via JSTNETS SETID in the OPTASK LINK, i.e., JSTNETS/CNTRL/9/MAGIC AIR CNTRL/1//. Reference: para 4.11-2
5. Be cognizant of the packing limits in use and the impact of multinet, interferometer effects and jamming on single pulse packing limits. Also be cognizant of any frequency assignment constraints on the alteration of packing limits, and the impact of packing limit changes on transmit capacity. Coordinate changes to packing limits if conditions warrant and constraints permit. Reference: para 4.11-3

For Stand Alone JTIDS/Link 16 Networks

6a. Reserve TNs 00200 through 00227 for preassigned E-3 reference points, and be sure the 552 ACW is aware of this convention. Reference: para 5.7.2

7a. Assign source track numbers (STNs) to all JTIDS/Link 16 participants as five octal digits. For daily training networks suggest assign STNs to C^2 units between 00001 and 00076 starting with 00001 and to fighters between 00230 and 00277 starting with 00230. Reference: para 5.7-1

8a. Assign TADIL J track number (TN) blocks to all surveillance platforms as five octal digits between 00300 and 07776 starting with 00300. For daily training networks for the E-3 assign a block of 700 octal (448 decimal) and for the Rivet Joint a block of 300 octal (192 decimal). The E-3 guidance may be applied to the CRE/CRC. Reference: para5.7-1

9a. For daily training networks which mix IJMS and TADIL J, the E-3 should match its SRN block to its assigned TN block and its DLRN block equal to its TN block less the leading zero. The Rivet Joint requires no SRN block per se, but will use a SRN block which is equal to its TN block when it simulcasts on both IJMS and TADIL J. With this convention, no distribution of SRNs via OPTASK LINK will be required. Reference: para 5.7-1

For JTIDS/Link 16 Networks Which are a Part of a Multi TADIL Network

6b. Coordinate with the R/SOC to reserve DLRNs 0200 through 0227 for preassigned E-3 reference points, and be sure the 552 ACW is aware of this convention, and to reserve DLRNs 0230-0277 for fighter

STNs. Also ensure that the DLRN blocks assigned to the E-3 and CRC/CRE in the standing OPTASK LINK are at least 700 octal in size and that the DLRN block assigned to the Rivet Joint is at least 300 octal in size. If the standing OPTASK LINK uses all available DLRNs on TADIL A and B participants (i.e., none available for JTIDS/Link 16-only C^2/surveillance units), coordinate with the R/SOC to reserve suitable DLRN blocks and PU/RU numbers for the JTIDS/Link 16-only C^2/surveillance units. Reference: para 5.7-2

7b. Assign source track numbers (STNs) to all JTIDS/Link 16-only C^2/surveillance units covered in the standing OPTASK LINK equal to their PU/RU number plus two leading zero digits. JTIDS/Link 16-only C^2/surveillance units not covered should be given a STN equal to the lowest unassigned PU/RU number plus two zero leading digits. Assign STNs to all fighters starting with 00230 and sequencing through 00277. Reference: para 5.7-2

8b. For all JTIDS/Link 16-only C^2/surveillance units covered in the standing OPTASK LINK, assign TADIL J track number (TN) blocks equal to their assigned DLRN block plus a zero leading digit. JTIDS/Link 16-only C^2/surveillance units not covered should be given a TN block equal to the lowest unassigned DLRN block of suitable size plus one zero leading digit. Reference: para 5.7-2

9b. For daily training networks which mix IJMS and TADIL J, the E-3 should match its SRN block to its assigned TN block. The Rivet Joint requires no SRN block per se, but will use a SRN block which is equal to its TN block when it simulcasts on both IJMS and TADIL J. With this convention, no distribution of SRNs via OPTASK LINK will be required. Reference: para 5.7-3

10. Consult the deconfliction server to determine if other networks are being operated within line of sight and range of any of the platforms in your network. If so, independent operations must be ensured throughout the use of either cryptokey or time offset. Time offset requires the use of a relative time base for at least one of the networks involved. The offset should be at least 10 minutes. Also, remember, the Rivet Joint must use Zulu time until new software due in late CY 99 is released. Reference: para 6.8-1/2

11. Decide whether to use a relative or external time based network. To use an external time based network at least the net time reference (NTR) must be capable of using GPS time as an external time reference (ETR). The block 30/35 E-3 is currently so capable. The use of a relative time base will be assumed by network participants. Reference: para 6.13-1

    a. If using a relative time based network, all ETR capable platforms should disable ETR. In addition, a Zulu time base will be assumed. If a different time base is to be used for network independence, it may be best to coordinate by voice (i.e., subdividing a package of fighters into to two independent networks). If the OPTASK LINK is appropriate, we suggest the use of the GENTEXT SETID, for example

    GENTEXT/THE LINK 16 NETWORK WILL EMPLOY LOCAL TIME AS THE TIME BASE RATHER THAN THE NORMAL ZULU TIME.//

    b. If an external time base is to be used, the network participants must be informed via the OPTASK LINK message. We suggest the use of the GENTEXT SETID for this too, for example

    GENTEXT/NETWORK WILL EMPLOY EXTERNAL TIME REFERENCE USING GPS TIME. PLATFORMS IMPLEMENTING ETR SHOULD ENABLE. ANY NTR MUST BE ETR CAPABLE.//

12. If the network is to be relative time based, one, and only one, participant must be designated net time reference via the OPTASK LINK. The DUTY SETID is used, for example, Reference: para 6.13-1

    DUTY/964 AWACS:E-3:MAGIC/NTR//.

    If it is an external time based network one NTR should be designated, but other ETR capable participants can designate themselves NTR if necessary to enter the network (i.e., if they are not within line of sight or are not within range of other active network participants).

13. Most network participants are designated initial entry message transmitters as part of the network design. However, when entering on an initial entry transmitter other than the NTR, coarse synch may take longer to achieve. Reference: para 6.4

14. We have the following recommendations regarding synch:

    a. All network participants should obtain a good time hack premission and ensure that their terminal clock is set within a few seconds of the coordinated network time prior to net entry. For an ETR based network the time hack should be Zulu time. Reference: para 6.12-3

    b. F-15s should not designate themselves NTR at the AFMSS, but rather enter NTR in the cockpit just prior to forming the network. NTR selected as part of the initialization data on the DTM can inadvertently lead to multiple NTRs and their attendant problems. Reference: para 6.5-1

    c.When first entering a network, the F-15s should enter time so the flight processor

    will send a one minute uncertainty to the terminal increasing the likelihood of entry. Reference: para 6.5-1

    d. The block 20/25 E-3 should always enter a time uncertainty which is a odd

    multiple of 6 seconds to ensure they cannot become synchronized with the TADIL J initial entry message being transmitted by a Class 2 terminal equipped platform. Reference: para 6.5-4

    e. To properly terminate their operation in one network and join/form another, a flight of F-15s should all perform a master reset before any one of them attempts to enter the new network, otherwise they may reenter on the old network. Reference: para 6.6-2

f. When it becomes necessary to handover the NTR function from one platform in the network to another, the handover can be somewhat sloppy with there being two or no NTR for a short time, but the time should be no longer than a few minutes. This time duration is paced by navigation quality, not time quality itself. Reference: para6.6-3

g. To avoid the problem of entrants in close proximity interfering with each other's initial entry message, the best approach is for F-15 pilots to coordinate their entry (i.e., start net entry at about the same time). That way they all have achieved coarse synch before any has achieved fine synch and can interfere. However, if staggered entry is performed on occasion and the pilots complain about occurrences of slow net entry when parked close together on the ramp, the wing/unit manager should suggest that once in the network (i.e., fine synch) the non NTRs switch their terminals to radio silent until all of the flight has achieved fine synch. Reference: para6.10-2

h. If operators/pilots experience synchronization problems, normal corrective measures do not work, they are operating where atmospherics may be a problem, and they see link performance which seems to defy normal rules for line of sight and the range mode of the network in which they are operating, they should suspect anomalous propagation and, for synch, can take steps to ensure that they enter a network which does not exhibit such propagation difficulties. For F-15s, it has been found that if anomalous propagation effects are experienced, delaying net entry until they are above 20000 ft will eliminate the problems. Forming a small-scaled local network is another option. Reference: para 6.11-2

15. Make reference to the cryptokey utilization plan and the cross reference table of the network which is to be operated and determine which short titles to associate with the required CVLLs. This association must be sent to the network participants, preferably using the CRYPDAT element of the OPTASK LINK for the network.

a. For simple daily training in which the same network may be used day-in and day-out, it is simplest to establish a standing key fill procedure. However, the wing manager should ensure that adequate training for deployed operations in which other than standing key fill procedures are required is accomplished. Reference: para 7.11

16. Ensure that wing platforms operating in Link 16 networks are doing so under valid frequency assignments. Reference: para 8.17

a. For local training operations ensure that there is an appropriate frequency assignment

- Consult with AF JNDF to determine availability of existing assignments suitable for wing use.

- If no existing assignment is suitable, work with the local installation frequency manager (IFM) to request and obtain suitable frequency assignment(s). The AF JNDF can help.

b. Be familiar with Air Force Manual 33-120 entitled Radio Frequency (RF) Spectrum Management which will permit the wing manager to understand the frequency assignments.

17. Ensure that frequency deconfliction is performed for all Link 16 operations in which his platforms take part and that the use of Link 16 by his platforms is scheduled in the deconfliction server data base. Reference: para 8.13

a. It is recommended that the wing manager of the base hosting a training operation take the lead in the deconfliction of the operation, and that the wing manager of the base hosting a training operation schedule the entire operation on the deconfliction server.

b. However, if the operation of a single Link 16 network is to be reported upon via the individual wing managers of the platforms comprising the network, the wing managers must coordinate on their reported TSDFs so as to report an accurate total TSDF for the network operation.

18. The network manager must decide on which navigation modes will be used, how and by who. Geodetic navigation is always operating in an active terminal. Relgrid navigation must be activated via a relgrid origin and navigation controller (NC). Reference: para 9.13

a. The relgrid origin must be coordinated among all relgrid participants and the same origin entered by all. Use the REFPOINT SET ID of the OPTASKLINK message.

E.g., REFPOINT/GRIDORG/ALPHABRAVO/ 2715N-06430W/-//

b. One, and only one, NC must be designated and so selected by that F-15C. Recommend the network manager assign NC only to flight level permitting the flight leader to designate which F-15C from within the flight. Use the DUTY SETID of the OPTASK LINK message.

E.g., DUTY/390 FS:F-15C:HOGGER/NC//

The NC can designate himself at the AFMSS and/or the cockpit. We recommend that it be done only in the cockpit. A pilot might use a preloaded DTM with NC designated and not be aware of that fact which could lead to two NCs inadvertently being extant in the network.

c. Otherwise, refer to items under the in-garrison checklist

Troubleshooting Guide

Coarse Synchronization

1. If after a start net entry command a participant is unable to achieve coarse synch it is most likely a time or cryptokey related problem. Check to be sure that:

   a. The participant's clock time is correct (i.e., set to the time base that has been coordinated upon). If necessary, obtain a time hack from the NTR or another active network participant by voice. If the participant is the first to enter the network, this may reveal that the NTR has incorrect time.

   b. The participant's time uncertainty is large enough. If not, if possible, try a larger time uncertainty. For the E-3 this can be entered by the comm tech. For the F-15 pilot entry of time will overwrite the short default uncertainty of 6 seconds per day since synched with a 1 minute uncertainty

   c. The participant's cryptokey is correct. This includes assuring that the correct title (e.g., AKAT 3109) is being used and that the right day's cryptokey is being used (e.g., correct date or current cryptoperiod designator)

   d. If the participant is the first to enter the network, ensure that the NTR's cryptokey is correct by voice.

2. If time and cryptokey are correct, and coarse synch cannot be achieved, ensure that the participant is within line of sight of a network participant which is an initial entry message transmitter.

3. If time and cryptokey are correct and the participant is within line of sight of an initial entry transmitter, we have found occurrences of loose or fully disconnected antenna cables, even in F-15s. These should be checked.

4. If the range to the NTR may be within 200 ft of the range to other participants already in the network (e.g., other F-15s in the flight on the ramp who have already achieved fine synch), long entry time may reflect a staggered network entry process and interference of the receipt of the NTRs initial entry message. Suggest a coordinated entry process whereby all F-15s start net entry at about the same time so all will achieve coarse synch before any (except the NTR) achieve fine synch. If staggered entry attempted, request other participants already in the network go to radio silent until entering participant achieves coarse synch so that will not interfere with the NTR's initial entry message.

5. If the NTR is ETR capable, and the network is to be operated with a relative time base which is significantly different than GPS (Zulu) time, check that the NTR has not enabled ETR. If he has, the network time base is GPS time, not the correct time base.

Fine Synchronization

6. If after coarse synch has been achieved, a participant cannot achieve fine synch, it may be due to one of the following

   a. The participant is using an incorrect network initialization data set, and the RTT NPG time slot assignments in his network do not match those in the correct network (i.e., the network that has been coordinated upon). Check with a network participant by voice. If the participant is the first to enter the network, it may be that the NTR is using an incorrect network initialization data set. Check with him by voice.

   b. There may be another network operation in progress which has not been coordinated with to ensure independence. In some cases this will be clear since PPLIs from unexpected participants will be seen once in coarse synch. In other cases, the PPLIs of the "offending" participants aren't seen. Diagnosing this is more difficult, but knowledge of past offenders may help. In any case, the solution to the problem is to time offset the network which is being formed, and to contact the offending participants to avoid the problem in the future.

   c. The participant may be initialized as a primary user and not be within RTT range (300 nm) of a network participant. Check received PPLIs to see if they are within RTT range. If not, select radio silent for about 5 minutes and then switch back to normal transmit. In the 5 minutes, the terminal should passively achieve fine synch and a clock model adequate to communicate until the participant is within RTT range.

   d. There may be anomalous propagation effects present. Check received PPLIs to see if they defy normal line of sight conventions. If so, suggest wait until above 20000 ft altitude (i.e., above the propagation effects) before attempting to enter the network.

Systemic Problems

7. If the network time quality appears to be dropping and there has recently been a handover of the NTR function, check to see that the new NTR has so selected himself (i.e., has a time quality of 15). For F-15s which do not display ownship time quality, position quality will follow ownship time quality down, so one reason for a dropping position quality is a dropping time quality. If the new NTR has so selected himself, check to make sure the old NTR has deselected himself (or is gone!) If he has not, that too could cause a dropping of both time and position quality as each participant tries to resolve the two differing NTR sources.

8. If the network is relative time based and a participant's time quality is fluctuating, if the participant is ETR capable, check to be sure he has not enabled ETR.

Navigation

9. If using geodetic navigation and low Pqs are experienced it may be that

   a. There is not a sufficient number of high quality sources, or there are but you are in a low GDOP area or there is but one high quality source and you are not moving so as to traverse a sufficiently large arc about the source fast enough to overcome the drift rate of your INS.

b. You have low time quality (Tq). Tq is not displayed in the F-15C. Low Tq can occur if you are a primary user (the usual F-15C setting for normal range mode networks) and out of range or line of sight of another network participant with a good Tq or if the net time reference (NTR) has left the network and another NTR has not been designated.

c. You are radio silent doing passive synch and there are not sufficient sources to estimate both position and time.

10. If using relgrid navigation and low RPqs are experienced it may be that:

a. Your RPq is so low and your distance from other relgrid participants so short that your terminal will not start up relgrid navigation i.e., TOA processing. This can be prevented before takeoff by keeping your RPq above 0 with combinations of INS alignment/visual update by your NC and yourself. Once airborne an option is too have one flight member separate from the flight far enough to see the RPqs jump up and then for him to return.

b. You have been in a fixed position with respect to the NC for a long time and you are in an area of poor GDOP regarding other high quality relgrid participants or you have recognized the problem just cited but are not moving so as to traverse a sufficiently large arc about the NC fast enough to overcome the drift rate of your INS.

List of Acronyms

AF FMA	Air Force Frequency Management Agency
AF JNDF	Air Force JTIDS Network Design Facility
AFC	Area Frequency Coordinator
AFMSS	Air Force Mission Support System
AJ	Anti-jam
AOC	Air Operations Center
ASCIET	All Services Combat ID Evaluation Team
ASIT	Adaptable Surface Interface Terminal
ATCRBS	Air Traffic Control Radar Beacon System
C^2	Command and Control
CARIBROC	Caribbean Regional Operations Center
CJCSI	Joint Chiefs of Staff Instruction
CMS	Control Monitor Set
CPD	Cryptoperiod Designation
CRE	Control and Reporting Elements
CVLL	Cryptovariable Logical Label
dB	Decibels
DISA	Defense Information Systems Agency
DLO	Data Link Operator
DLRN	Data Link Reference Number
DME	Distance Measuring Equipment
DOD	Department of Defense
DTM	Data Transfer Module
ETR	External Time Reference
EW	Electronic Warfare
F/F	Fighter to Fighter
FAA	Federal Aviation Administration
FASCFAC	Fleet Area Control Scheduling Facilities
FDL	Fighter Data Link
FEBA	Forward Edge of the Battle Area
FP#2	Flight Position 2
GAAC	Geographic Area Assignment Coordinator
GDOP	Geometric Dilution of Precision
HUR	High Update Rate
ICCP	Integrated Communication Control Panel
ICO	Interface Control Officer
IFF	Identification Friend or Foe
IFM	Installation Frequency Manager
IJMS	Interim JTIDS Message Specification
INS	Inertial Navigation System
IPF	Interference Protection Features
JICO	Joint Interface Control Officer

JMTOP	Joint Multi TADIL Operating Procedures
JMTS	Joint Multi TADIL School
JNDL	JTIDS Network Design Library
JNL	JTIDS Network Library
JTIDS	Joint Tactical Information Distribution System
LLD	Low Level Detector
LOS	Line Of Sight
LVT	Low Volume Terminal
MA	Mobile Aircraft
MCTSSA	Marine Corps Tactical Systems Support Activity
MER	Message Error Rate
MIDS	Multifunctional Information Distribution system
MIL STD	Military Standard
MOA	Military Operating Area
MOOTW	Military Operations Other Than War
MPCD	Multipurpose Color Display
MSEC	Message Security Key
MSGID	Message Identifier
NADGE	NATO Air Defense Ground Environment
NAVEMSCEN	Navy Electromagnetic Spectrum Center
NC	Navigation Controller
NDL	Network Design Load
NEA	Net Entry Aid
NFD	Network Floppy Disk
nm	nautical miles
NORM	Normal transmit mode
NPG	Network Participation Group
NSA	National Security Agency
NTR	Net Time Reference
OFP	Operational Flight Program
OPTASK LINK	Operational Data Link Tasking Message
POC	Point Of Contact
PPLI	Precise Participant Identification and Location messages
Pq	Position quality
PU	Participating Unit
R/SOC	Regional/Sector Operations Center
R^2	Reporting Responsibility
REFPOINT	Point of Reference
RF	Radio Frequency
RJ	Rivet Joint
RPq	Relative Position quality
RRN	Recurrence Rate Number
RSC	Radio Set Control
RTT	Round Trip Timing message
RU	Reporting Unit
s/f	slots per 12 second frame

SESOCC	Southeast SOCC
SETID	Set Identifier
STANAG	Standardizing Agreements
STN	Source Track Number
TACAN	Tactical Air Navigation system
TADIL J	Tactical Digital Information Link J
TDMA	Times Division Multiple Access
$\mathbf{T_I}$	Time interrogation was received by the NTR in network time
TN	Track Number
TOA	Time Of Arrival
TPA	Track Production Area
Tq	Time quality
$\mathbf{T_R}$	Time of Arrival of the Reply in its clock time
TSDF	Time Slot Duty Factor
TSEC	Transmission Security Cryptokey
UHF	Ultra-high Frequency
US&P	US and her Possessions
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
VORTAC	Combination of VOR and TACAN
VSD	Vertical Situation Display
WAD	Western Air Defense Sector
WSO	Weapons Surveillance Officer